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Proceedings of the
Seventh Pacific Science Congress

of the

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Held at Auckland and Christchurch, New Zealand,
2nd February to 4th March, 1949

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CONTENTS

SYMPOSIUM ON TERRESTRIAL FAUNAS OF THE PACIFIC: DISTRIBUTION, ECOLOGY AND SPECIATION; RELATION TO MAN

Page

Report of the Standing Committee on Distribution of Terrestrial Faunas in the Inner Pacific. By Ernst Mayr, Chairman of the Standing Committee 5
Fragments of a Papuan Ornithogeography. By Ernst Mayr 11
Ability of Amphibians to Cross Sea Barriers, with Especial Reference to Pacific Zoogeography. By George S. Myers 19
Distribution of the Gekkonidae in the Pacific Area. By Charles McCann 27
Notes on Mammalian Distribution in the Cape York Peninsula. By G. H. H. Tate 32
Paleogeographical Significance of Fresh-water Fish Distribution in the Pacific. By George S. Myers 38
The Distribution of the Family Galaxiidae. By G. Stokell 48
The Size of Island Faunas. [*Abstract.*] By Eugene Munroe 52
Distribution and Speciation of Land Birds on Offshore Islands, Northern New Zealand. By E. G. Turbott 53
On the Evolutionary and Distributional History of *Malacopteron* (Aves, Timaliidae). [*Abstract.*] By K. H. Voous 58
The Morphological, Anatomical, and Distributional Relationship of the Arctic and Antarctic Fulmars (Aves, Procellariidae). [*Abstract.*] By K. H. Voous 60
Phenotypical Differentiation of Endemic Birds in Relation to Island Size in Micronesia. By Y. Yamashina 61
The Affinities of *Pityriasis* of Borneo. By M. Hachisuka 67
Parasites and Evolution. [*Abstract.*] By T. W. M. Cameron 69
The Distribution of Tapeworms in the Pacific Area and the Conclusions to be Drawn Therefrom. By Robert A. Wardle 70
Studies on the Morphology and Biology of *Strongyloides papillosus*. [*Abstract.*] By Khan M. A. Basir 74

Entomological Aspects

Competition in Relation to Distribution in Some Insects of the Western Pacific. By M. A. Lieftinck 75
Twenty-five Years of Migration of the Painted Lady Butterfly, *Vanessa cardui,* in Southern California. [*Abstract.*] By Charles H. Abbott 82
The Phylogeny of the Papilionidae. By Eugene Munroe 83
Melanism and Size in Relation to Climate Among New Zealand Insects. By J. T. Salmon 87

SYMPOSIUM ON ECONOMIC ENTOMOLOGY: QUARANTINE PROBLEMS AND BIOLOGICAL CONTROL

Report of the Standing Committee on Economic Entomology

Introduction. By C. E. Pemberton, Chairman of the Standing Committee 91
Economic Entomology in Hawaii. By C. E. Pemberton 91
Economic Entomology in Guam and Micronesia. By C. E. Pemberton 94
Biological Control in California from 1939 to 1949. By Harry S. Smith 96
Economic Entomology in the Philippines since 1939. By L. B. Uichanco 98
Agricultural Entomology in Indonesia, 1939-1948. By J. van der Vecht 100
Notes on Economic Entomology in the Canadian Pacific Region. By W. E. van Steenburgh 109
Some Aspects of Australian Entomological Research since 1939. By Frank Wilson 113
Economic Entomology in New Zealand. By L. J. Dumbleton 118

Regional Pest Faunas

The More Important Insect Pests of British Columbia. Assembled by K. M. King from contributions by H. Andison, E. R. Buckell, R. Glendenning, J. D. Gregson, K. M. King, J. Marshall and H. A. Richmond 121
Recent Developments in Forest Entomology in Canada. [*Abstract.*] By J. J. de Gryse 148

Page

The Oriental Fruitfly (*Dacus dorsalis* Hendel) in Hawaii. By D. T. Fullaway 148

Notes on Entomological Work in the Philippines since 1939, with Special Reference to that on the Oriental Migratory Locust (*Locusta migratoria manilensis* Meyen). By Faustino Q. Otanes 164

Notes on Economic Insects of Micronesia. By R. G. Oakley 174

Control of Insect Pests

Control of Livestock Insects in British Columbia by the New Organic Insecticides. By J. D. Gregson 185

Chemical Control of Wireworms in Western Canada. By A. P. Arnason, K. M. King and W. B. Fox 188

Development of Concentrate Orchard Sprayers in Canada. By J. Marshall and J. R. W. Miles 196

Some Wartime Problems of Insect Infestation in Australian Stored Wheat. By Frank Wilson 206

Protection of Canadian Grain in Storage and Transit. By H. E. Gray and W. N. Keenan 210

Breeding Spring Wheats for Resistance to Wheat Stem Sawfly Attack. By A. W. Platt and C. W. Farstad 215

Biological Control of Insects

The Biological Control of Insects in Hawaii. By C. E. Pemberton 220

Some Problems of Biological Control of Insect Pests in the Philippines. By Silverio M. Cendana 223

The Rhinoceros Beetle (*Oryctes rhinoceros* L.) Situation in the Palau Islands and the Introduction of Two Scoliid Parasites to Combat this Pest. By T. R. Gardner 229

Biological Control of Insect Pests in British Columbia. By A. B. Baird and J. H. McLeod 232

Natural Control of the California Red Scale in Untreated Citrus Orchards in Southern California. By Paul DeBach, C. A. Fleschner and E. J. Dietrick 236

Population Studies of the Long-tailed Mealybug and its Natural Enemies on Citrus Trees in Southern California, 1947. [*Abstract.*] By Paul DeBach, C. A. Fleschner and E. J. Dietrick 249

Observations on the Life History of the Mariana Coconut Beetle, *Brontispa mariana* Spaeth, and the Introduction of Parasites for its Control. By W. Harry Lange, Jr. 249

Artificial Infestation of Plants with Pest Insects as an Aid in Biological Control. By Harry S. Smith and Paul DeBach 255

Biological Control of Insects in New Zealand. [*Title.*] By D. Miller 259

Culture of Entomophagous Insects. By Stanley E. Flanders 259

Some Natural Enemies of Snails of the Genus *Achatina* in East Africa. [*Abstract.*] By Francis X. Williams 277

Biological Control of Insects and Plants in Fiji. By B. A. O'Connor 278

Biological Control of Weeds

The Initiation of the Biological Control of Weeds in the United States. [*Abstract.*] By Harry S. Smith 294

Some Aspects of the Control of Weeds by Insects. By Frank Wilson 294

Progress in the Entomological Control of St. John's Wort in Australia. By Frank Wilson 300

Quantitative Studies on the Biological Control of St. John's Wort (Klamath weed) in California. By C. B. Huffaker 303

Legislation and Quarantine

Insect Quarantines Within the Pacific. By C. E. Pemberton 314

The Philippines' Plant Quarantine and Inspection Service. By Gonzalo Merino 317

A Review of Canadian Insect Pests and Plant Disease Legislation. By W. N. Keenan 323

Quarantine Problems of Hawaii. By C. L. Richie 328

Entomological Aspects of Insect Quarantine in New Zealand. By L. J. Dumbleton 331

Page
The Plant Quarantine System in New Zealand from the Entomological Point of View. By A. M. W. Greig 334

General

Relationship Between Insects and Mushrooms. By R. Heim 348
Some Features of the Distribution of Insect Life on Philippine Mountains. By Leopoldo B. Uichanco 350
Activité Saisonnière de la Faune Economique Neo-Calédonienne. Par F. Cohic 357
The Establishment and Spread in New Zealand of the Wasp *Vespa germanica*. By C. R. Paterson 358
Insect and Rodent Control Methods in the Far East Command, U.S. Army. By Austin W. Morrill, Jr. 362
Pacific Areas and the Biological Control of Agricultural Pests. By Paul Vayssiére 366

DIVISIONAL DISCUSSION ON WHALING IN THE PACIFIC

Whaling in the North Pacific. [*Discussion.*] By Carl L. Hubbs 368
Whales in the Pacific Sector of the Southern Ocean. [*Abstract.*] By N. A. Mackintosh 369
Whaling on the British Columbia Coast. By Gordon Pike 370
A Contribution to the Study of the Humpback Whale Based on Observations at New Zealand Shore Stations. By W. H. Dawbin and R. A. Falla 373

DIVISIONAL DISCUSSION ON PROBLEMS OF BIRD MIGRATION IN THE PACIFIC

Migrations of Shore Birds in the Central Pacific. By Rollin H. Baker 383
On the Origin of Bird Migration in the Pacific. By Ernst Mayr 387
Movements of Pelagic Sea-birds in the Indo-Pacific Region. By D. L. Serventy 394

SYMPOSIUM ON MARINE BIOLOGY IN THE PACIFIC BASIN, WITH SPECIAL REFERENCE TO FISHERIES

The Fisheries Research Board of Canada – its Organization and Programme. By W. A. Clemens 408
Fisheries Research on the Canadian Pacific Coast. By R. E. Foerster 413
The Experimental and Physiological Approach in Fisheries Biology. By William S. Hoar 421
The Trawl Fishery on the Pacific Coast of Canada. By J. L. Hart 425
Technological Aspects of Fisheries Research by the Fisheries Research Board of Canada. [*Abstract.*] By Neal M. Carter 428
The School of Fisheries, University of Washington. By R. Van Cleve 429
Problems in Fisheries Management for Pelagic Schooling Fish. By Frances N. Clark 436
Philippine Fisheries Today and Tomorrow. By Albert W. C. T. Herre 440
Philippine Bangos Culture: a Successful Method of Salt Water Pond Culture. By Albert W. C. T. Herre 449
The Pond Culture of Mullet in the New Territory, Hong Kong, China. By Albert W. C. T. Herre 457
The Philippine Fishery Programme. By H. W. Terhune, H. E. Warfel and J. A. Clague 460
Biological Successions in Disharmonic Bays and Lagoons, and Their Improvement for Fisheries Purposes. By D. Miyadi and T. Habe 477
An Analysis of the Constitution of the Intertidal Fauna and Flora of the Rocky Coast of New South Wales, and Some Comments on its Relationship to Those of Other Temperate Areas of the Southern Hemisphere. [*Abstract.*] By Elizabeth C. Pope 479
Studies on Plankton of the Bering and Chukchi Seas and Adjacent Areas. By Martin W. Johnson 480
A View of New Zealand Fisheries. By L. R. Richardson 500
Biology of the Marine Spiny Crayfish, *Jasus lalandii* (Milne-Edwards) in New Zealand Waters. By C. A. Bradstock 504

Page

Sur la Collection des Stomatopodes de l'Institut Océanographique de l'Indochine. Par R. Serene 506
Première Liste de Poissons Collectés en Nouvelle-Calédonie. [*Résumé*.] Par M. Legand 508
Première Contribution à l'Etude du Genre *Stolephorus* Lacépède (Clupeidae) en Nouvelle-Calédonie. [*Résumé*.] Par M. Legand 508
The Acclimatization of the Pacific Oyster (*Ostrea laperousii* Schrenck = *Ostrea gigas* Thunberg) Upon the West Coast of North America. By Trevor Kincaid 508
The Development of the Dogfish Fishery in British Columbia. By W. E. Barraclough 513
A Survey of Marine Wood Borers in the Pacific by the United States Navy. Recorded by Charles H. Edmondson 519
Timbers of Unusual Resistance to Marine Borers in Hawaiian Waters. By Charles H. Edmondson 529
Coral-dwelling Organisms as Destructive Agents of Corals. By H. Utinomi 533
Conservation Aspects of Pacific Marine Fisheries. By Robert C. Miller 536
The Indo-Pacific Fisheries Council. By G. L. Kesteven. [*Abstracted* by M. W. F. Tweedie.] 537

DIVISIONAL DISCUSSION ON FRESH-WATER BIOLOGY AND INLAND FISHERIES

Game Fish Problems in British Columbia. [*Abstract*.] By W. A. Clemens 539
Control of the Pike-whitefish Tapeworm in Central Canada. By K. H. Doan 539
Factors Affecting the Freshwater Development of Pacific Salmon in British Columbia. By Ferris Neave and W. P. Wickett 548
The Objects of Fresh-water Fisheries Research. By K. Radway Allen 556
Factors Affecting the Size and Growth of Young Salmonidae in New Zealand. By Derisley F. Hobbs 562
Fresh-water Fisheries Research in New Zealand. By K. Radway Allen 575
The Influence of Chemical Constituents of Water upon the Mortality of Young Rainbow Trout. By T. Tomiyama and Y. Kojima 580

SYMPOSIUM ON PROTECTION OF NATURE, TERRESTRIAL AND MARINE, AND CONSERVATION PROBLEMS OF THE PACIFIC AREA

Report of the Standing Committee for Protection of Nature

Report of the Standing Committee for the Protection of Nature in and around the Pacific for the Years 1939-1948. By C. Skottsberg, Chairman of the Standing Committee 586
Report of the United States Member of the Standing Committee for the Protection of Nature in and around the Pacific. By Harold J. Coolidge 612
*Conserving the Alaska Fur Seals. By Victor B. Scheffer 615
*Fluctuations of the United States Big Game Populations during the Last Decade. By N. W. Hosley 620
*Management of Migratory Waterfowl (With Special Reference to Game Species). By Clarence Cottam and Cecil Williams 626
*The Federal Programme with Relation to Future Development of Pacific Fisheries. By Milner B. Schaefer 634
*Scientific Soil Conservation. By H. H. Bennett 639
*Conserving Wildlife in the National Parks. By Victor Cahalane 646
*Some Conservation Problems in Hawaii National Park. By Frank R. Oberhansley 652
*Progress in Forestry in the United States. By Lyle F. Watts 657
*Progress in Management of Large Mammals with Special Reference to the Wapiti in Jackson Hole. By Olaus J. Murie 666
*A Conservation Programme for Micronesia. By F. R. Fosberg 670
*Save-the-Redwoods. [*Abstract*.] By Wallace W. Atwood 673

---

* Papers included in the report of the United States member of the Standing Committee.

Page

Pacific Conservation Problems

Mesures de Conservation à Prendre pour la Sauvegarde de la Flore de la Nouvelle-Calédonie. Par A. Guillaumin 674
Protection de la Nature en Nouvelle-Calédonie. Par R. L. A. Catala 674
Rapport sur la Protection des Oiseaux Sauvages dans les îles Francaises de l'Océanie. Par M. J. Berlioz 679
Philippine Wildlife Problems. By Canuto G. Manuel 683
The Protection of Rare and Vanishing Fishes. By George S. Myers 691
The Impact of Man upon Nature in New Zealand. [*Abstract.*] By Robert Cushman Murphy 694
Protection of the Indigenous Flora of New Zealand. By W. R. B. Oliver 695
Effects of the Australian Opossum (*Trichosurus vulpecula* Kerr) on Indigenous Vegetation in New Zealand. By R. I. Kean and L. Pracy 696
Southern Seals: Population Studies and Conservation Problems. [*Abstract.*] By R. A. Falla 706
Regeneration of the Vegetation of Great King Island. By G. T. S. Baylis 706
The Relation of the Universities to Researches in the Conservation of the Fish and Wildife Resources of Canada. [*Abstract.*] By W. A. Clemens 708
Conservation of the Trumpeter Swan in Canada. By J. A. Munro 708
Progress in the Conservation of Natural Resources in Oregon. By Warren D. Smith 714
The Status of Steller's Albatross. [*Abstract.*] By Oliver L. Austin, Jr. 718
The Present Status of the Protection of Birds and Mammals in Japan. By N. Kuroda 719
The Protection of Nature in the Pacific with Relation to the New Development of a World Approach to International Conservation. By Harold J. Coolidge 727

SYMPOSIUM ON TERRESTRIAL FAUNAS OF THE PACIFIC : DISTRIBUTION, ECOLOGY AND SPECIATION; RELATION TO MAN

REPORT OF THE STANDING COMMITTEE ON DISTRIBUTION OF TERRESTRIAL FAUNAS IN THE INNER PACIFIC

By Ernst Mayr, Chairman of the Standing Committee

Ten years have passed since the last Pacific Science Congress. These ten years have brought to the Pacific the most terrible war ever inflicted on mankind. It has severely interrupted traffic and human relations, as evidenced among other things by the regrettable absence of Japanese scientists from the present Congress. The war affected the majority of the Pacific islands, has completely ravaged a few, and has led to the deplorable extermination of some of their most characteristic endemic elements. However, the war also has had some beneficial effects on the Pacific. It has led to an unprecedented interest in the nature, the people, and the scientific exploration of the Pacific. I dare say that more scientists have worked in the Pacific in the last four years than in the whole generation preceding it. The results of this activity are beginning to appear. Especially to be mentioned is the founding of a new journal, *Pacific Science,* published by the University of Hawaii. New institutions are the Pacific Science Board of the National Research Council, Washington, D.C., the South Pacific Commission, the Institut Français d'Océanie at Noumea, and the Koror Field Station of the Pacific War Memorial. A list of all scientific institutions in the Pacific area was recently published (Bushnell, 1948).

Of special interest to the student of terrestrial faunas are the numerous publications which have appeared during the past ten years. Without any attempt at completeness I would like to list some of them: The Pacific World series, including a general volume as well as volumes on mammals (Carter et al.); fishes and shells (J. T. Nichols and P. Bartsch); insects (Curran); reptiles and amphibians (Loveridge); *The Birds of the Southwest Pacific* (Mayr); *The Birds of the Philippines* (Delacour and Mayr); *Insects of Hawaii* (vols. 1-5) (E. C. Zimmerman); *List of New Guinea Birds* (Mayr).

Among more special ones are numerous papers on the faunas of the islands of the Pacific published by the Bishop Museum, a continuation of the reports of the Whitney South Sea Expedition, and of the Archbold Expeditions to the New Guinea area. Also numerous surveys have been made of the insect and particularly the mosquito fauna. The zoological results of the survey of Bikini before and after the atom bomb explosions are still unpublished. The results of some of the faunistic surveys made during the war by U.S. Naval Medical Research Units have already been published (Baker, 1948). In Micronesia, Japanese scientists have done a great deal to further our knowledge of the Pacific. The *Bibliographica Micronesica* by Utinomi (Fisher, 1947) gives a good insight into their many-sided activities. Since the war there have been scientific surveys in Micronesia under the auspices of the U.S. Commercial Company (e.g., botanical collections by Ray Fosberg) and by the Insect Control Committee for Micronesia. A summary of some of this work has been published by the National Research Council (1946, 1947). Many other individuals and agencies have made important contributions to the inventory of the fauna of the Pacific, but it is impossible in the present short report to give all of them the well-deserved credit.

PROBLEMS IN THE FIELD OF THE COMMITTEE

The exploration of the fauna of any region—and that of the islands of the Pacific is no exception—goes through two stages. The first one is that of taking inventory, and the second one is the causal analysis of the raw data. Work of this second stage is carried on principally in three fields which are best characterized by the three terms: ecology, zoogeography, and evolution. We come thus to the following classification of faunistic research.

1. The taking of the inventory.
   Characterized by collecting and taxonomic analysis.
2. (a) The study of habits and ecological requirements.
   (b) The analysis of origin and history of the faunas including a study of geological history and of dispersal facilities.
   (c) Speciation and evolution. A study of the multiplication of species and subdivision of species, and of their evolutionary changes.

This "pure" research is to be supplemented by a study of conservation needs.

INVENTORY

The inventory of the animal life of the Pacific is exceedingly uneven. It is virtually completed so far as birds are concerned, largely owing to the remarkable work of the Whitney South Sea Expedition. But even in birds some areas are still insufficiently known, like the mountains of Guadalcanal and of New Ireland and parts of New Guinea. The breeding place of some sea birds is still unknown, as for example, for *Puffinus heinrothi* and *Pterodroma becki.*

The inventory is much farther from completion in all other groups of animals. New species are still described even in medically so important groups as the mosquitoes. A principal reason for continued discovery of new forms is the exceedingly restricted range of most species and subspecies. Baker (1948) states that among the 104 kinds of resident land and fresh water birds of Micronesia no less than 97 (= 93 per cent) are endemic. Most of them, in fact, are restricted to a single island.

The entire faunas of vast areas are very insufficiently known, and this includes whole islands and groups of islands. It is the most urgent task to complete this inventory at the earliest possible moment. Otherwise it will be too late in many cases. The native fauna of entire islands have already been destroyed, as Zimmerman (1948) has described so graphically for Mangareva. Deforestation, the cultivation of large tracts, and the introduction of foreign pests, from the mongoose down to predatory ants and microscopic blood parasites, have resulted already in the extermination of many members of the Pacific fauna. Some of this destruction is inevitable and is proceeding rapidly at the present time, hence the need for an immediate inventory of the native fauna. Some of it can be prevented by appropriate conservation measures. An adoption of the measures proposed at conservation meetings (Coolidge, 1948) would go a long way toward saving what is left of the precious fauna of the Pacific.

The mere gathering and depositing of the fauna in collections is not enough. There are now hundreds of thousands of specimens in various museums which have not yet been studied scientifically for lack of funds to prepare them and to employ qualified taxonomists. There is the further difficulty of getting the results of such research published, particularly where large reports are involved. Financial aid for the institutions specializing in Pacific research is badly needed.

The History of the Pacific Fauna

There has been a good deal of clarification during the past ten years concerning the geological structure and history of the Pacific. The reckless landbridge builders of an earlier period, like Sarasin, Crampton, and Meyrick, were able to get support and encouragement from certain geologists. Today geologists are virtually unanimous in stating that the Pacific is an old and undisturbed ocean basin. The various archipelagos in the Pacific, east of the "Andesite Line", originated as outpourings of volcanic material through cracks of the ocean bottom. Currently the geologists are concerned with the following four interrelated chief problems of interest to the zoogeographer: (1) the ages of the islands, (2) their former size, (3) the position of submerged islands and archipelagos, and (4) fluctuations in ocean level (shore lines). Recent fluctuations of the shore line are largely due to the freezing and melting of the Pleistocene ice cap and correlated eustatic movements. Nearly all of the Pleistocene and post-Pleistocene shore lines are within 300 feet of the present ocean level. Older shifts of the shore line, as well as fluctuations exceeding the 300-foot amplitude, must have had different causes. Some of the work on ancient shore lines is summarized by Stearns (1945) and Cotton (1947).

The age of the islands is much more difficult to determine. Zimmerman (1948) has summarized the geological evidence which indicates an amazingly recent age (Pliocene-Pleistocene) of the Hawaiian Islands. Stearns (1944) sets the origin of the Samoan Islands as late Pliocene or early Pleistocene. These chronologies appear to be based entirely on geomorphological evidence, such as rate of erosion, stratification of lava flows and ashes, etc. There are no fossiliferous strata to permit more accurate datings, such as is possible for islands west of the Andesite Line, e.g., Lau, Fiji (Ladd and Hoffmeister, 1945; Hess, 1948).

The most exciting addition to our knowledge of the Pacific comes from the deep drilling at Bikini, Marshall Islands. Although the drill hole went down only to 2556 feet, it had already reached a lower Miocene marine fauna between 1790 and 2500 feet. Seismic records indicate that the reef coral deposits continue for another mile or so and that they are underlain between 6000 and 13,000 feet deep by igneous rocks. This indicates two things, first that in certain areas of the Pacific the bottom has been sinking for the greater part of the Tertiary and at a rather rapid rate at that, and secondly that there must have been a sizable amount of volcanic activity even early in the Tertiary, not only as late as the Pliocene as implied in most of the geological literature. It now appears possible that such archipelagos as the Tuamotus, Marshall, Gilbert, Ellice, and Phoenix Islands are the last remainders of once flourishing groups of high volcanic islands, such as the Hawaiian Islands are today.

The dropping of the sea level has apparently not proceeded at a uniform rate. Whenever there was a standstill, it would lead to a levelling off (through erosion) of some of the islands. Another sudden drop would lead to the origin of a submarine table-topped bank. In the course of recent echo-soundings many deeply submerged table-topped volcanic cones have been found in the western Pacific. These were described by Hess (1946) and termed *guyots.*

Just why the bottom should be dropping out under the Pacific is not quite clear. According to one view (Stearns, 1945a) it is the weight of the volcanic material that has poured out through numerous cracks which depresses the floor of the Pacific. According to another view (Wundt, 1948) it is the cooling off of the ocean floor which leads to an outflow of magma from underneath it. The evidence for the gradual sinking of the floor of the Pacific continues to pile up. Hobbs (1944) arrived at the same conclusion on an entirely different basis.

Whatever its causes are, the concept of the sinking of the Pacific is of great importance to the zoogeographer. It may help to reconcile the differences between the land bridge builders and the adherents of the permanency of oceans and continents. As Zimmerman (1948) points out, the Hawaiian fauna, with its rich contents of endemic and often rather isolated and archaic elements, could hardly be understood unless one assumes that it was derived in part from pre-existing high islands.

Whatever the configuration of the Pacific archipelagos was early or in the middle of the Tertiary, it seems certain that the volcanic outpourings were not distributed in the form of extensive land masses, as they were visualized by the early land bridge builders. Though the stepping stones may have been larger than they are now, they always were stepping stones, passable only for creatures capable of transoceanic dispersal. Many biogeographers seem to be unable to grant that many organisms have an amazing ability to cross water-gaps of considerable extent. Yet, the evidence all points that way. There is no better example to demonstrate the rapidity with which new islands are populated than Krakatau Island between Sumatra and Java, which was totally destroyed in 1883 by a volcanic explosion. Fifty years later its fauna was again as rich as that of other Malaysian islands of similar size and ecology (Dammerman, 1948). No land bridge was needed to accomplish this. That the building of land bridges is not only unnecessary but actually leads to zoogeographical difficulties can often be demonstrated merely by an analysis of existing faunas (Mayr, 1944 for the Timor region; Mayr, 1940 for western Polynesia).

DISPERSAL

The study of dispersal and dispersal facility, one of the most important branches of biogeography, has been strangely neglected. The capriciousness of chance dispersal has been as distasteful to the naturalist as has been random mutation in the field of evolution. But, just as chance mutation obeys definite laws, so does chance dispersal. It will be the task of the coming generation of biogeographers to work out these laws. Our ignorance in this field is nearly complete.

We want to know what percentage of castaways becomes successfully established. The rich indigenous bird fauna of Hawaii is due to thirteen colonizations (Mayr, 1943); the several thousand insect species of Hawaii have descended from less than 300 original colonists (Zimmerman, 1948).

We want to know which groups of animals are susceptible to transoceanic dispersal and which are not and why. We know that mammals are dependent on rafts and that indigenous terrestrial mammals are absent from islands that are too far distant from the mouths of rivers, while the air is the medium of transport for most smaller animals (flying as well as flightless).

We want to know whether ordinary trade winds are more important for dispersal or the rare but violent tropical hurricanes. Much distributional evidence indicates that the latter are a more efficient agent of dispersal than steady winds, but no thorough analysis has ever been made.

We want to know whether this phenomenon of colonization is a steady process that goes on for century after century or whether there are sudden spurts, separated by long periods of complete inactivity. It will be hard to determine just how steady this process of colonization is, but that it has been going on for millions of years is obvious. The earliest immigrants have had time to evolve into prosperous endemic families, later ones into genera, species, and subspecies, while the most recent immigrants are still indistinguishable from the parental populations in the ancestral home. This has been shown for the birds of the Hawaiian and Galapagos Islands and for those of the Papuan region. It is evidently also true for the molluscs and insects of Polynesia and the Hawaiian Islands (Zimmerman, 1948). More detailed investigations are desirable.

This outlines some of the problems connected with dispersal; many additional ones could be mentioned.

THE ORGANIZATION AND THE WORK OF THE COMMITTEE

In conclusion I would like to say a few words about the future work of the Committee. It was formed by the late Dr. C. M. Cooke, Jr., at the last Pacific Science Congress at the suggestion of Dr. Hatai. It is at this Congress that the Committee is meeting for the first time. Its policies are still in the formative stage and are up for discussion at the present time. In order to get this discussion started, I shall make the following proposals:

(1) Programme.
    (a) Maintenance of a bibliography on the fauna of the Pacific.
    (b) Organization of a symposium at each Pacific Science Congress.
    (c) Report on the progress in the field of the Committee, to be prepared and delivered by the Chairman of the Committee.
    (d) Research on the conservation needs in the Pacific and advisory services to the active conservation organizations, in collaboration with the Standing Committee for Protection of Nature In and Around the Pacific.

(2) Organization.

Election by the Committee of a new chairman and secretary at each Pacific Science Congress.

Election of such new members to be contingent on their having qualified through their published work. Such elections, however, to be limited so that the total size of the Committee at no time exceeds twelve members. Election to be governed also by the policy to have as many countries as possible participating, provided they have qualified scientists. Three members to retire at each Congress in order to maintain the activity of the Committee.

It is believed that a properly functioning committee could exert a powerful influence in stimulating and coordinating research in the Pacific.

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FRAGMENTS OF A PAPUAN ORNITHOGEOGRAPHY

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THE bird fauna of New Guinea was, a generation ago, the least known bird fauna of any part of the world. The bird life of the interior and particularly of the mountains was largely unknown. However, during the past thirty years expeditions have gone to New Guinea at the rate of about one every two years and have brought back an enormous amount of information. This permitted the preparation of a systematic and distributional "List of New Guinea Birds" (Mayr, 1941) which may serve as a convenient basis of a zoogeographical analysis. A complete analysis of the 300 genera, 650 species, and over 1500 subspecies of New Guinea birds would require much more space than is available here.

1. THE ZOOGEOGRAPHIC POSITION OF THE NEW GUINEA BIRD FAUNA

New Guinea is classified as part of the Australian region in nearly every zoogeographical treatise. The lack of placental mammals (except for bats and some rodents) and the wealth of marsupials seem to confirm this classification to the fullest extent. The phytogeographers, however, are by no means happy about this delimitation of biogeographic regions since the flora of the tropical belt from Malaya to the Solomons seems to form a unit which is strikingly different from that of temperate and arid Australia (e.g., Burkill, 1943). Among the students of invertebrates, also, much doubt has been expressed as to the justification for including the Papuan area with the Australian region, e.g., Michaelsen (1922) for the Oligochaeta and Karny (1929) for Gryllacridians.

Whether the bird fauna of New Guinea agrees better with the pattern indicated by the mammals or that of the plants shall be investigated in the present section.

The Families of New Guinea Birds. An analysis of the New Guinea bird fauna on the basis of the families is not very revealing. Omitting sea birds, representatives of 36 families of non-Passerines breed on New Guinea. Of these families no less than two-thirds (24) are worldwide, additional ones are widespread in the Old World (6) or in the Old World tropics (1). This leaves precisely 5 small families. Three of these (Casuariidae, Megapodiidae, and Aegothelidae) are Australo-Papuan, one is Australo-Papuan and Oriental (Podargidae), and one Oriental and Papuan (Hemiprocnidae).

The Passerine birds are more revealing. There are 29 families and (within the Muscicapidae sensu lato) subfamilies. Of these only 4 are worldwide (Hirundinidae, Motacillidae, Turdinae, and Corvidae). Five are Old World (Alaudidae [1 part-American species], Timaliinae [1 American species], Muscicapinae, Oriolidae, and Ploceidae), 4 are Old World Tropical [with an occasional temperate zone species or subspecies] (Pittidae, Campephagidae, Dicruridae, Zosteropidae), 4 are Old World [excepting Australia] (Sylviinae, Laniidae, Sturnidae [1 part-Australian species], Nectariniidae). This leaves 12 families and subfamilies which more clearly reveal their origin and zoogeographic relation. Ten of these are Australo-Papuan (Malurinae, Pachycephalinae, Falcunculinae, Artamidae, Grallinidae, Cracticidae, Philonorhynchidae, Neosittidae, Climacterinae [Certhiidae, part], and Meliphagidae). One is almost exclusively Papuan (Paradisaeiidae) [with 4 of its forms spilled over into north Australia], and one is Oriental and Australo-Papuan (Dicaeidae). The families which are Papuan or Australo-Papuan include most of those with the highest number of New Guinea species, like the Meliphagidae (61), Malurinae (24), and Pachycephalinae (24). On the other hand, there is not a single family of which the chief area of distribution is the Oriental and the Papuan Region—to the exclusion of Australia.

The Genera of New Guinea Birds. An analysis of the genera provides an even clearer picture. In order to avoid any bias, I am using with only slight changes the genera admitted in my New Guinea list (1941). I am omitting all oceanic and fresh-water birds, including Ciconiiformes and Anseriformes. The results of this analysis are presented in Table 1.

TABLE 1

A. *Old and New World*

Accipiter, *Spizaetus,*[1] Haliaetus, Pandion, Falco, Circus, Grus, Rallus, Porzana, Gallinula, Fulica, Columba, Tyto, *Otus,* Caprimulgus, *Chaetura,* Hirundo, Anthus, *Turdus, Lanius,* Corvus.

B. *Widespread Old World*

Milvus, Hieraaetus, *Alcedo,*[1] *Saxicola,* Oreocincla, Acrocephalus, *Phylloscopus.*

C. *Old World Tropics* (an occasional species or subspecies extending into the Temperate Zone)

Machaerhamphus,[1] Aviceda, Excalfactoria, Turnix, Porphyrio, Centropus, Halcyon, Merops, Pitta, Mirafra, Coracina, Cisticola, Oriolus, Dicrurus, Zosterops, Nectarinia.

D. *Oriental-Australo-Papuan*

Haliastur (A), Irediparra (P), Rallina (O), Amaurornis (O), Ducula (P), Chalcophaps (P), Macropygia (P), *Caloenas*[1] (O), *Tanygnathus* (O), Loriculus (O), Cacomantis (P), Chalcites (P), Ninox (P), Eurostopodus (P), Collocalia (O), *Hemiprocne* (O), *Ceyx* (O), Eurystomus (O), *Aceros* (O), Lalage, Edolisoma (P), Pomatorhinus (O), Megalurus (O), Rhipidura (P), Aplonis (P), Dicaeum (O), Erythrura (O), Lonchura.

The presumable ancestral home is stated in parentheses: A = Australian, P = Papuan, O = Oriental.

[1] Genera which do not occur in Australia are in italics.

E. *Papuan* (not endemic)

Includes genera clearly Papuan that have spread to nearby regions.

Megapodius (AP), Poliolimnas (AP), Ptilinopus (O), Eudynamis (O), Tanysiptera (O), Monarcha (O), Phonygammus (AP), Craspedophora (AP), Eupetes (AP).

F. *Australo-Papuan*

Synoicus, Eulabeornis, *Trichoglossus,*[2] *Opopsitta, Probosciger, Cacatua,* Geoffroyus, Alisterus, Podargus, *Aegotheles,* Alcyone, Dacelo, Drymodes, *Orthonyx,* *Sericornis, Acanthiza, Gerygone,* Myiagra, Microeca, Tregellasia, Poecilodryas Heteromyias, *Pachycephala, Colluricincla, Cracticus, Chlamydera, Ailuroedus, Neositta,* Climacteris, *Ramsayornis,* Conopophila, *Myzomela, Xanthotis, Lichmera, Meliphaga, Philemon.*

[3] In italics are members of Australo-Papuan families or subfamilies.

G. *Australian* (not endemic)

Uroaetus, Ieracidea, Geopelia, Aprosmictus, Scythrops, Cinclosoma, Seisura, Petroica, Artamus, Sphecotheres, Gymnorhina, Melithreptus, Entomyzon, Neochmia.

H. *Papuan with Oriental Relationship*

Henicopernis,[3] Megaloprepia, Larius, *Caliechthrus,* Mino, *Chaetorhynchus.*

[3] Endemics in italics.

I. *Papuan with Australian Relationship*

Casuarius, *Megatriorchis,*[3] *Talegalla, Aepypodius,* Eos, Lorius, Vini, *Oreopsittacus, Neopsittacus, Psittaculirostris,* Micropsitta, *Psittrichas, Syma, Clytoceyx, Crateroscelis, Androphobus, Todopsis, Clytomyias, Chenorhamphus, Pomareopsis.* Monachella, *Peneothello, Pachycephalopsis, Eulacestoma, Rhagologus, Pitohui, Cnemophilus, Amblyornis, Xanthomelus, Archboldia, Daphoenositta, Timeliopsis, Glycichaera, Oedistoma, Toxorhamphus, Melilestes, Melipotes, Melidectes, Oreornis, Ptiloprora, Pycnopygius, Oreocharis, Paramythia.*

[3] Endemics in italics.

J. *Endemics with Uncertain Relationship* (mostly very characteristic Papuan elements)

Harpyopsis,[3] *Anurophasis, Rallicula, Gymnocrex, Megacrex, Gymnophaps, Reinwardtoena, Henicophaps, Gallicolumba, Trugon, Otidiphaps, Goura, Psittacella, Rhamphomantis, Uroglaux, Melidora, Campochaera* (O), *Amalocichla* (O), *Ifrita, Melampitta, Eugerygone, Machaerirhynchus, Arses, Peltops, Pachycare, Manucodia, Seleucides, Drepanornis, Epimachus, Astrapia, Parotia, Lophorina, Paradigalla, Macgregoria, Diphyllodes, Cincinnurus, Pteridophora, Paradisaea, Loboparadisea, Loria, Melanocharis, Rhamphocharis, Oreostruthus.*

Two obvious conclusions can be drawn from these data.

(1) *The Australo-Papuan element by far outweighs the Oriental element.* Even if we include all the widespread elements with the Oriental group and omit the Papuan endemics from the calculations there are 45·7 per cent Australian or Australo-Papuan genera as against 35 per cent Oriental.

(2) *There is a high degree of striking endemism in the Papuan region,* in addition to other typically Papuan elements that are not endemic. This amounts to about 45 per cent of all the genera (E, G, H, I).

This element includes entire subendemic families or subfamilies (like the Paradisaeidae, Casuariidae), as well as such striking genera as *Harpyopsis, Megacrex, Trugon, Otidiphaps, Goura, Psittacella, Clytoceyx, Ifrita, Melampitta, Eugerygone, Peltops, Psittrichas, Androphobus, Eulacestoma, Amblyornis, Daphoenositta, Timeliopsis, Melipotes, Oreocharis,* and *Paramythia.*

2. Differences Between Birds and Plants

These first results of the analysis indicate that the bird fauna of New Guinea resembles the mammalian fauna in the strong prevalence of Australian types or at least of types which it has in common with Australia. There is an apparent discrepancy between these findings and those of the students of plants and invertebrates, referred to above. In an analysis of the flora of New Guinea the botanist Lam (1934) summarizes his conclusions in four points. These points are herewith quoted, together with my own comments, based on the distribution of birds.

"(a) There are no relic-endemics known at present."

What "relic endemics" are is more or less a matter of definition. There are no endemic families in New Guinea, although the Paradisaeidae are almost endemic. However, there is a large number of endemic or subendemic genera, including many that are quite isolated, such as listed above under (J). I would therefore be inclined to consider statement (a) not to apply to birds.

"(b) There is a strong neo-endemism, especially at higher altitudes."

This is also true for birds. This endemism concerns genera of widespread families as well as endemic species of non-endemic genera.

"(c) Asiatic floral elements prevail, even in the mountains; Polynesian ones come next, and Australian-Antarctic ones apparently last, Australian ones being best represented in the mountains and savannahs."

In birds the opposite is true. The Australian and Australo-Papuan elements make up the majority of the bird fauna, and the Asiatic element is a poor second. There is no Polynesian element. Much of this biota was first discovered in Polynesia and has therefore been listed in biogeographical papers as "Polynesian". The heartland of this biota, however, is New Guinea, as I have emphasized previously (Mayr, 1941, p. 212), and it is misleading to label this genuinely Papuan fauna as Polynesian. Merrill (1945, p. 212) comes to a similar conclusion as far as plants are concerned. It seems that there is no "Polynesian" biota in the strict sense of the word (but see Copeland, 1948). Even those genera that reached the height of development in the Polynesian area are originally of Papuan or Australian descent. Only few of the Papuan elements have sufficiently great dispersal facilities to reach Polynesia, hence the Polynesian fauna is composed of only a fraction of the Papuan one. Ripley and Birckhead (1942) have analyzed in detail the colonization of Polynesia by doves of the *Ptilinopus* group as a typical illustration of the Papuan origin of a Polynesian element.

"(d) Western relations are particularly strong with the Moluccas, the Philippines and Celebes."

Yes and no. The Moluccas are the western outlier of the Papuan Region and contain an impoverished Papuan bird fauna (with a considerable admixture of Asiatic elements). The Papuan element in Celebes is no larger than one would expect on the basis of the distance involved and the Australo-Papuan element in the Philippine bird fauna is negligible. It consists of *Cacatua* (1), *Trichoglossus* (1), *Gallicolumba* (1), *Irediparra* (1), *Megapodius* (1), *Ptilinopus* (6), *Poliolimnas* (1), *Eudynamis* (1), *Ninox* (1), *Gerygone* (1), *Rhipidura* (2), *Artamus* (1), *Pachycephala* (2), and possibly also *Apoia* (1). [Number of Philippine species in parentheses.]

To this are to be added some widespread species of eastern relationship: *Rallus philippensis*, *Porzana tabuensis*, *Amaurornis olivaceus*, *Chalcophaps indica*, *Cacomantis variolosus*, *Hirundo tahitica*, *Edolisoma morio*, and *Megalurus timoriensis*.

So much about Lam's theses and my own comments. I might mention that not all phytogeographers are equally impressed with the strictly Asiatic nature of the New Guinea flora. Merrill (1945), although following Wallace in applying the term Malaysia to the entire region from the Malay Peninsula to the Papuan region, recognizes that "two sub-areas seem to be clearly distinguishable, one centred around the Sunda Islands—Sumatra, Java, Borneo, and of course the Malay Peninsula—and the other about New Guinea and its adjacent islands". But Merrill agrees with the other phytogeographers in considering the New Guinea flora to belong to the Malaysian one and to differ strikingly from the Australian flora.

3. The Causes for the Contrast Between Plants and Birds

What is the reason for this discrepancy between the findings of the ornithologist and the botanist? Since both discuss the same area, it is obvious that geographical-geological controversies can be eliminated from the discussion. This leaves two possible causes:

(a) The dispersal or colonization facilities (or both) of plants and of birds are very different (ecological differences).

(b) The rates of evolution of the two groups are very different.

The facts on hand seem to indicate that both causes are responsible, but there are too many unknowns involved to be certain.

(a) *Ecological differences.* As Rensch (1936, p. 22) and others (e.g. Mayr, 1941b) have pointed out, birds in spite of their excellent dispersal potentialities are more easily stopped by water gaps than most other groups of animals. At the same time, there is much evidence that plants disperse more easily than is admitted by some botanists (Steenis, 1934-1935; Skottsberg, 1925). This is the view held by Guppy (1906), Gibbs (1917), Setchell (1935), and others. As far as colonization is concerned, conditions are reversed for birds and plants. Birds are easy colonizers since as mobile warm-blooded animals they carry their own environment with them, while the germinating seed must find a sympathetic environment if it is to succeed.

Can these ecological differences between birds and plants account for their distributional difference?

It is now generally agreed that during the Tertiary there were no permanent land connections in the unstable area between the Sunda and the Sahul shelves. Distribution had to go on by island hopping. This was done by plants, birds, insects, and by other animals. The earliest birds that reached Australo-Papua became the progenitors of a vigorous fauna, the Australo-Papuan fauna, but an all too frequent repetition of these colonizations was prevented by the respect most birds have for water gaps. On the other hand, the repeated and sometimes long lasting connections between New Guinea and Australia permitted such a free faunal interchange that it is impossible to say whether such families and subfamilies, as the honey-eaters (Meliphagidae), the brush-tongued lories (Loriinae), the wren-warblers (Malurinae), and the whistlers (Pachycepalinae) are more typically Papuan or Australian. The independence of birds from habitat restrictions leads to the remarkable phenomenon that the nearest relatives of many birds of the central Australian brush savannahs and semideserts are found in the steaming lowland or the misty mountain forest of New Guinea, such as of *Malurus* (*Todopsis, Clytomyias*), *Acanthiza, Gerygone, Pachycephala, Cinclosoma, Coracina,* etc., etc. A shift of habitat seems not nearly the problem to a bird that it is to a plant. The Malayan plants with their comparatively great dispersal facilities found congenial conditions throughout the equatorial belt as far east as Fiji and Samoa, except in the few places (Lesser Sunda Islands, parts of Celebes, Moluccas, and of southern New Guinea) where rainfall is insufficient. The result has been the development of a Malayo-Papuan flora which extends through this entire humid equatorial belt. A similar distributional picture has been found for certain groups of animals, for example, by Karny (1929) for the Gryllacridians. The reason why this biota has been unable to prosper in Australia, except to a very slight extent in humid eastern Australia, appears to be twofold, principally, as stated, because these forms are unable to undertake the drastic ecological changes of which some birds are capable.

This point is further emphasized by the behaviour of the Australian plant forms that have penetrated the Malay Archipelago. On Borneo, for example, there are five habitats in which edaphic conditions have permitted colonization by a not inconsiderable number of Australian species (Richards, 1943). This includes the high altitudes in the mountains, sandy beach forests, heaths, and some swampy habitats. There is no evidence that a similar infiltration of Australian animal types has occurred in these habitats, unless they are directly dependent on some of the plant species. It is evident from these data that the distribution of plants is much more immediately dependent on climate and edaphic factors than is that of animals.

A second reason for the difference between the distribution of plants and that of birds seems to be that plants (and some groups of animals) seem to be older than birds and that, as far as plants are concerned, the Australian habitat was already filled to capacity by well adapted indigenous species when the later colonists from Malaya appeared.

(b) *Different Rates of Evolution.* It has recently been shown that many plants, particularly trees, have had an exceedingly slow evolution. Others, like some herbaceous plants, have had evolutionary rates that compare favourably with those of birds and mammals. If, on the average, the evolutionary rate of plants is considerably slower than that of birds, one would expect a higher degree of endemism in the birds. This would mean that the following evolutionary levels might have been reached by those forms that became isolated in the New Guinea region in early Tertiary: birds into subfamilies and isolated genera, plants into species and less well differentiated genera. This degree of differentiation, of course, is what is reported in the literature for the two groups.

It seems to me that the facts stated under (a) and (b) help to dissolve most of the contradictions that seem to exist between the origin of plants and birds in the Papuan area.

4. The History of the New Guinea Biota

The Geological-paleogeographical Background. The available geological evidence suggests the following history of the Australo-Papuan area: New Guinea and the Malayan Islands were apparently situated in the same shelf-sea during late Mesozoic times. How much of Malaysia and Australo-Papua was then occupied by land and how much by shallow seas is impossible to say, but the evidence suggests a rather free faunal exchange between Asia and Australo-Papua. This would have been an opportune time for the ancestors of the Paradisaeidae, Dicaeidae, Pachycephalinae, Loriinae, Malurinae, Ptilonorhynchidae, and certain subgroups of Muscicapinae to reach the Australo-Papuan region, but a later period for this colonization seems much more probable.

During the early Tertiary the shelf fractured into a western (Sunda Shelf) and an eastern (Sahul Shelf) component. Most or all of the intervening area between Borneo and New Guinea became submerged at that time. This rather drastic isolation of Malaya from Australo-Papua permitted the development of the very distinct endemic Papuan bird fauna. Sometime early in the Tertiary it appears that New Guinea and Australia also became separated, a separation the effects of which were accentuated by the rapidly increasing aridity of Australia. It seems as if this isolation of the Papuan biota may have reached its highest degree in the Oligocene or early Miocene. From that time on more and more islands were folded up between the Sunda and the Sahul Shelves and became available as stepping stones between Asia and New Guinea. Finally, Australia and New Guinea became again connected towards the end of the Tertiary.

I have spoken of "New Guinea" in this historical survey as if this island had had its present configuration ever since it originated. Undoubtedly this is not correct. The New Guinea of today is a very recent geological structure and the heavy earthquake activity on the island, as well as the precipitousness of many slopes, indicates that it is the scene of heavy tectonic activity even today. Most of the mountain ranges go no further back than the middle of the Tertiary. Prior to that New Guinea was presumably an archipelago, somewhat like the Moluccas or the Solomon Islands of today.

5. Continental Drift and the Papuan Biota

The orthodox interpretation of the history of the Australo-Papuan biota is that the position of Australo-Papua relative to the Asiatic continent has not changed materially since the late Mesozoic. This viewpoint, though the majority opinion, is not shared by all biogeographers. Lam (1934), in particular, has endorsed emphatically the concept of continental drift. He believes that the Australo-Papuan continent has "crashed" only recently (Pleistocene?) into the Moluccan-Melanesian chain of islands after having become separated from the Antarctic continent in early Tertiary (Eocene?). Rensch (1936) is undecided, but believes that many distributional phenomena are unintelligible unless one accepts continental drift.

To me this does not seem to be the case. On the contrary, there are numerous facts against continental drift.

(1) If the drift hypothesis were correct, one would expect two faunas in New Guinea, an old endemic Australian one with South American and South African relationships and a very recent Malayan one. However, as I have shown elsewhere (Mayr, 1944), the Australo-Papuan fauna is characterized by a complete gradation between the oldest, very isolated endemics and the most recent immigrants. This makes sense only if Australia were available to Asiatic immigrants throughout the Tertiary.

(2) The existence of endemic or subendemic tropical Papuan families, such as the birds of paradise, is inexplicable if late Tertiary drift is accepted. Neither is that of the Australo-Papuan groups (see above) in which the endemic Papuan element is about as strong as the Australian one.

(3) If Australo-Papua had crashed only recently into the Moluccan-Melanesian chain, one would expect a strong relationship between the Moluccan and Melanesian biota in contrast with the Papuan one. However, as Hediger (1934) has shown, this is not the case. Not a single one of the endemisms among the birds of Northern Melanesia (*Woodfordia, Guadalcanaria, Meliarchus, Edithornis, Ortygocichla, Reinwardtoena crassirostris, Halcyon bougainvillei, Nesoclopeus woodfordi, Nesasio, Accipiter princeps, A. eichhorni, Tyto aurantia* and *manusi, Henicophaps foersteri, Rhipidura dahli,* etc.) is more closely related to Moluccan than to New Guinea forms. The cases among the terrestrial mollusks cited by Rensch (1936, p. 288) are amenable to a different interpretation. The absence of certain Melanesian-Moluccan species from New Guinea seems to be caused in many cases by ecological factors (habitat differences, enemies, competitors) rather than by biogeographical ones.

(4) The frequency of endemic genera (of Australo-Papuan origin) found in the Moluccas and the Celebes region cannot be explained unless the Australo-Papuan area has been in its present position for a long period of time (Rensch, 1936). The same is indicated by the great number of genera that are rich in species both in the Malayan and in the Australo-Papuan region.

These various objections would seem to rule out continental drift, at least as far as the Cenozoic is concerned. This agrees with the mammalian evidence (Simpson, 1943). There are many facts that would seem to favour a modified continental drift for early or middle Mesozoic (e.g., the distribution of the gymnosperms [Buchholtz, 1948] and of many south temperate groups of plants), but they have little bearing on the distribution of the present Papuan bird fauna.

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ABILITY OF AMPHIBIANS TO CROSS SEA BARRIERS, WITH ESPECIAL REFERENCE TO PACIFIC ZOOGEOGRAPHY

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1. Introduction

Alfred Russel Wallace (1892) and most zoogeographers since his time have accepted the presence of endemic amphibians as one of the prime diagnostic features of continental islands, and the absence of these animals as indicative of truly oceanic origin. Amphibians as a group are delicate creatures, extremely susceptible to salt water, to dessication, and to the heat of the sun, and since they do not possess wings, it is difficult to imagine how they could cross sea barriers. Recent work, however, suggests that amphibians not only can cross salt-water barriers, but have done so upon many occasions.

In 1915, the late W. D. Matthew, in the most important single contribution to zoogeography since the time of Wallace, pointed out that the Greater Antilles have probably had no dry-land connection with the American continents during the Cenozoic.[1] In 1938, I pointed out that primary fresh-water fishes have never reached the West Indian islands, and that this fact alone strongly indicates that a continental connection of the Antilles occurred before the Cenozoic, if it ever existed at all. In the same year (1938), Darlington published an extremely important paper on the origin of the Greater Antillean fauna, in which he concluded that fauna gives no indication of a continental connection. The Greater Antilles are, however, extremely well supplied with frogs, mostly belonging to the large genus *Eleutherodactylus,* which is richer in species in Cuba, Hispaniola, Puerto Rico and

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[1] See also Matthew, 1918 and 1939.

Jamaica than in any continental area of comparable size. Darlington, as did Matthew before him, concluded that the few basic types of mammals and amphibians from which the West Indian fauna has plainly arisen arrived by flotation or hurricane winds. It is the purpose of the present paper to examine what is basically the same problem in regard to certain Pacific islands, chiefly the East Indies.

2. Sweepstakes Routes and Filter Bridges

Simpson (1940) has nicely illustrated the types of dispersal patterns displayed by mammals in the crossing of land-bridges and barriers. Routes which have involved the crossing of sea barriers by terrestrial creatures are Simpson's "sweepstakes routes", in which only certain animals—those fitted for "island-hopping"—hold winning tickets. Land bridges which have been crossable only by some animals and not others are termed "filter-bridges" because they filter out some of the fauna. The well-known intermittent bridge from Siberia to Alaska is a good example, and the present Isthmus of Panama is another.

In my ichthyological paper at this Congress (Myers, 1953), and in two previous ones (Myers, 1938; 1949) I have demonstrated how strictly primary fresh-water fishes are limited to continental land masses. Darlington (1948) gives the evidence in greater detail. Primary fishes are almost completely stopped by any kind of sea barrier; their ability to make use of sweepstakes routes is more limited than that of any other large vertebrate group.

Applying these findings to the East Indies, with full knowledge of Mayr's recent paper on Wallace's Line (1941), I have concluded that there has been no dry-land connection of Sundaland (that is, Borneo, Bali, and the islands to the westward which were evidently united with Asia in the late Cenozoic) with any land or islands to the eastward during the entire Cenozoic and perhaps never. In other words, beyond Sundaland, to the east, the migration route to New Guinea and Australia has always been a sweepstakes route involving island hops. In this, my conclusions agree with those of Simpson based on mammal evidence.

In the Philippines, however, my conclusions based on the fishes do not agree completely with those of others, including Darlington (1948), who considered the fish evidence. A more searching study of fish distribution than Darlington made convinces me that the Palawan-Calamianes chain to the north of Borneo, and the Sulu-Mindanao chain to the north-east of Borneo were actually connected by dry land with North Borneo during the late Cenozoic emergence of Sundaland. But the fish evidence is very strong that the islands north of the Calamianes and Mindanao were never connected with Sundaland, and I believe the fish evidence to be far more critically important in such instances than that of the other vertebrates.

North Borneo has a somewhat depauperate fish fauna today, and it is quite evident that North Borneo itself, as well as the Palawan and Sulu land bridges, has acted as a filter bridge in filtering out much of the teeming primary fish-fauna of the rest of Borneo. In exactly the same way, East Java and Bali have impoverished primary fresh-water fish faunas and have acted as a filter bridge which has enabled only a small proportion of the Sundaland fresh-water fish fauna to reach Bali. Yet the fish evidence is clear that there has been no dry-land bridge across Lombok Strait during the Cenozoic, and that there have been bridges to Palawan and Mindanao.

3. Island-hopping

Darlington (1938) has intelligently and critically discussed the methods by which terrestrial animals conduct island-hopping campaigns. Naturally, these over-water migrations are involuntary, but they are much more effective than many zoologists realize. Except by the hand of man, two methods are available, flotation and wind-dispersal. Flotation may involve actual swimming, as with the hippopotamus which reached Madagascar (Simpson, 1940), but for smaller animals it probably usually occurs on those natural rafts cast out by rivers in flood and which upon very, very rare occasion reach another land intact. (The fact that the flotation route is unavailable to primary fresh-water fishes is probably one reason why they are such poor island-hoppers.) Wind dispersal is available only to smaller animals which may be borne aloft by the wind or blown by the storm winds of high velocity, often in pieces of vegetation. The latter type of wind-dispersal is much more likely to occur in regions where hurricanes or typhoons are prevalent, such as the West Indies. However, tornadoes which suck up all sorts of things—even fishes in waterspouts—to a great height, are locally important dispersal agents in many places.

Primary fresh-water fishes appear to have indulged in island-hopping at only two places in the whole East Indian complex, from the Calamianes to Mindoro and across Lombok Strait. In the first instance only one species is concerned, in the second, two. Even if the numbers of species concerned were somewhat larger, the general picture would be unchanged. There is no possibility, geological or otherwise, that Borneo and Celebes have been connected by dry land (Mayr, 1944) and no primary fresh-water fish has gotten from one to the other except two or three almost certainly introduced by man. Yet amphibians have crossed from Sundaland to Celebes, and the crossing appears to have been directly from Borneo.

4. Amphibian Island-hoppers

It is not possible to cover all the amphibian groups of the East Indies in this paper but I have selected five frog families (Pelobatidae, Bufonidae, Hylidae, Ranidae, and Polypedatidae)[7] as representative and concentrated upon these. In addition I have considered the Caecilians.

The Caecilians are burrowing creatures, and one might suspect that they are not good island hoppers. They are found from the mainland through Sumatra, Java, Borneo, Basilan, Mindanao and Palawan. They probably occur also on the Calamianes although not yet reported there. Nowhere—here or in other parts of the world—do they give evidence of having crossed sea barriers. (Their presence on the

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[7] See Noble (1931) for the limits and composition of these groups. Van Kampen (1923) has given lists of East Indian species by islands, and his lists are useful if one takes into account the subsequent systematic change and family shifts, most of which are mentioned by Noble. Taylor's Philippine work is also very useful (1921).

Seychelles Islands of the Indian Ocean is strong evidence for the continental connection of that group.)

The Pelobatid toads have about the same East Indian range as the Caecilians; they are totally absent east of Wallace's Line but in the Philippines have succeeded in reaching some of the islands to the north of Mindanao (Dinagat, Samar) but not Luzon. The family is rather primitive and is known to have existed in Asia as far back as the Oligocene (Noble). (An endemic subfamily in the Seychelles appears to reinforce the caecilian evidence for continental connection of that Indian Ocean group, since the pelobatids do not seem to be good island-hoppers.)

The common toads, Bufonidae (equals the subfamily Bufoninae of Noble) appear to be a fairly young and aggressive group. Of the East Indian genera, *Pedostibes* runs through the islands of the Sunda Shelf, including Palawan and Mindanao (Taylor, 1921), but the aquatic *Pseudobufo* is confined to the Malay Peninsula, South Borneo and Sumatra. Like many other Sunda animals, it is unknown in North Borneo and Java. The commonest genus, *Bufo,* swarms in many species on the islands of the Sunda Shelf, but there are comparatively few species in North Borneo, Mindanao, and the Palawan-Calamianes chain. Celebes, however, has an endemic *Bufo* (*celebensis*) and has been invaded by the mainland and Sunda species *B. biporcatus.* Evidently *biporcatus* entered Celebes rather recently, *celebensis* a long time ago. Finally, Lombok has a presumed endemic species, *B. cavator,* which is close to or identical with *biporcatus.*

The Hylid tree frogs, like the Leptodactylids, once had a broader range and must have occurred in the Indo-Malayan region a long time ago, like the marsupials. They are not found there now, but swarm in Australia and New Guinea. The family arose from ancestors similar to those of the Bufonidae (i.e., Leptodactylidae). There is but one Australian-Papuan genus (*Hyla*) but in addition there are six species of the endemic genus *Nyctimystes* in New Guinea (Loveridge, 1948). *Hyla* is not confined to the New Guinean-Australian continental shelf, but also extends westward to Halmaheira, Buru, Timor, and Sumba, and eastward to the Solomons. There seems no doubt at all that the Solomons forms got there over sea-barriers, and the existing species in Halmaheira, Sumba, etc., do not look like relicts of a Mesozoic invasion from Asia. They, too, may be island-hoppers from Australia and New Guinea.

The Ranids form a large part of the frog fauna everywhere from the Asiatic mainland to Luzon, the Solomons and Fiji, but, strange to say, have penetrated only the northermost part of Australia. Most of the species are aquatic. The family is scarcely known fossil, and is probably more recent in origin than any of those mentioned above. Its classification is still poorly understood and in a fluid state. I have not, therefore, attempted to base many conclusions on the separate genera or subgenera which happen to be recognized at the present date. *Rana* (the common pond-frogs) is the dominant genus almost everywhere the family exists, but is almost certainly not a particularly "natural" genus. It extends to Luzon and to the Solomons. *Ceratobatrachus,* the strangest genus of the entire region, is known only from the Solomons, and must have been there a long time. *Batrachylodes* is also a Solomons endemic. *Cornufer* and *Platymantis* extend from

Sundaland to the Fijis; they are also found in the Solomons but neither they nor any other frogs have been reported from the New Hebrides or other intermediate groups. It has been suspected by Darlington (1948) that the two Fijian species were carried there by man but Brown and I (1949) have just studied the Fijian frogs and find them to be different from their close relatives in the Solomons. They seem to be endemic species, but it is difficult to believe that they have been blown or drifted from the Solomons, against prevailing currents and winds. If related forms were to be found in the poorly explored New Hebrides and Santa Cruz groups, island-hopping would be easier to believe. If the Fijian species did arrive without the help of man, they deserve recognition as the champion island-hoppers among all frogs.

Other ranids of the region are the localized, monotypic *Simomantis* and *Oreobatrachus*, known only from Mt. Kinabalu, North Borneo, and *Nyctixalus*, with two endemic species in Java. *Oocidozyga*, with two exceedingly common mainland and Sundaland species, runs up through the Philippines to Luzon and has reached Celebes and Flores. This aggressive genus has certainly made several sea-barrier crossings. Finally, *Staurois*, a genus whose limits are yet undetermined, appears to leave Sundaland only north of Mindanao.

The Polypedatid tree frogs (sometimes called Rhacophorids) form a probably young family, derived from the Ranids, and common in Africa, Madagascar, and tropical Asia. *Philautus* is a mainland and Sundaland genus which gets beyond the Sunda Shelf only in the Philippines, where it reaches Negros, Leyte, Panay and Mindoro. *Polypedates* (*Rhacophorus*) is a large and dominant mainland genus which is abundant in species only out to the edge of the Sunda Shelf. But three endemic species exist in Celebes, a couple more in the northern Philippines, and the protean, ubiquitous, mainland species, *P. leucomystax*, has spread as far as Luzon, Celebes and Timor.

The remaining amphibian families should really enter our discussion but there is not time to consider them and they illustrate no island-hopping techniques not already illustrated.

5. Discussion

The groups which migrated eastward through the island a long time ago, became extinct in south-east Asia and the Archipelago, and now flourish in Australia and New Guinea, are here illustrated by the Hylidae. Their migrations took place so long ago that it is not worth-while to speculate much upon their island-hopping abilities. That *Hyla* has reached the Bismarks and the Solomons is, however, interesting, since the migration assuredly involved island-hopping of no mean kind.

Groups which, though old, have apparently never been able to cross Makassar and Lombok Straits (Wallace's Line) are illustrated by Caecilians and Pelobatidae. The former, however, have never gone beyond the primary fresh-water fishes in the Philippines, but the Pelobatids have island-hopped as far north as Samar.[3]

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[3] The presumed New Guinea pelobatid, *Lechriodus* (*Batrachopsis*) is now known to be a leptodactylid.

Modern Asiatic groups of which only certain genera have been stopped by the old sea barrier beyond Sundaland are illustrated by the Bufonidae and Polypedatidae, and the identity and relationships of the sweepstakes winners among them show that some of the island hops have been older (endemic species of *Bufo* and *Polypedates* in Celebes, for example) and some far more recent (*Bufo biporcatus* and *Polypedates leucomystax* east of Wallace's Line).

Groups in which few genera besides local endemics appear to have been long restricted by sea-barriers of reasonable width are illustrated by the Ranidae. These aggressive, common frogs have swept clear through the Archipelago to northernmost Luzon, to Australia, and to the Solomons—with two species in the distant Fiji Islands. Their headquarters are in Africa and tropical Asia, but they have been in the Archipelago a long time. *Ceratobatrachus,* so common in the Solomons, or a near ancestor of it, must have lived in New Guinea at one time, but nothing remotely resembling it has yet been discovered there.[4]

If the Ranidae are such good island-hoppers as the East Indian evidence leads me to believe—perhaps the champion sweepstakes winners among the amphibians—it may seem strange that no ranid has ever reached the Greater Antilles, which have ranid neighbours close by in Florida and Central America. The explanation is not far to seek. The West Indian fauna is almost completely Central or South American in origin; almost nothing has reached even Cuba from Florida. Ranids are rather recent immigrants in North America and even more recent in Central and South America. They still form only an insignificant part of the Central American fauna, and but one species has penetrated into South America.

Common, dominant species are the usual sweepstakes winners. *Rana, Ooeidozyga, Cornufer, Polypedates* (especially the excessively common *leucomystax*), *Hyla*, and *Bufo* are the usual island-hoppers in the Indo-Australian Archipelago.[5] The winners surely must also possess such ecological tolerances and live in such a habitat that they are likely to be transported by flotation or winds, but so little is known of such things among amphibians that we cannot speak with much assurance. For example, it might be supposed that burrowing frogs would be very poorly fitted, but most burrowing frogs congregate at open ponds in large numbers to breed and are then exposed to the same transportation methods as other species. Moreover, such cryptozoic amphibians often hide in vegetable debris which is easily transportable by the high winds of typhoons (see Darlington, 1938). On the other hand, the burrowing Caecilians do not congregate aboveground to breed; their larvae are aquatic, and are no more exposed to wind transport or flotation than primary fresh-water fishes.

As Darlington (1938) has shown, the distributional patterns exhibited by "sweepstakes winners" are regular. The mathematical chances of safe arrival over water barriers are such that we seldom see some islands of a chain skipped over by migrating forms. The middle East Indian amphibian pattern is thus perfectly normal for faunas composed of or derived from over-water migrants.

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[4] I doubt that the Solomons ever had a land connection with New Guinea, but it must be admitted that the absence of primary fresh-water fishes in both places (there is one photographic record of a primary fish from New Guinea) makes me fall back on the absence of Melanotaeniin fishes in the Solomons as the only proof from the fish side.

[5] *Eleutherodactylus* in tropical America belongs in the same class.

One feature deserves especial note. In spite of the fact that the Philippines north of the Calamianes and Mindanao simply cannot have had dry-land connection with Sundaland, nearly all the existing Sundaland amphibian families have pushed far to the north. Even the old Pelobatids, which have been completely stopped to the southward at Wallace's Line, have crossed sea-barriers in the Philippines. Only the Caecilians and the Bufonidae[9] have not done so. That this barrier and ones to the north of it have been so commonly crossed is undoubtedly due in part to the fact that the sea-barriers have been narrow, which Darlington shows is a very potent factor. Moreover, the islands on either side of each narrow Philippine barrier are usually of large extent, another potent but so far underemphasized factor. Thirdly, this area is the one in which northward travelling typhoons (hurricanes) are prevalent. It is no wonder, then, that Philippine sea-barriers have been crossed more frequently than others.

6. The New Zealand Frogs

The three New Zealand species of *Leiopelma* belong to the most primitive existing frog family, the Ascaphidae, the only other living members of which are the three subspecies of *Ascaphus truei* (Mittleman and Myers, 1949) found from northern California to British Columbia. Although no fossils are known, the family almost certainly arose in the Mesozoic, and undoubtedly once had a very much broader geographic range. Frogs are probably older than either placental mammals or the dominant Cenozoic primary fresh-water fishes. The oldest known true froms are from the Upper Jurassic, but their relationship to modern groups is debatable.

Ascaphus and *Leiopelma* are not very similar in many respects. The American form is an aquatic frog inhabiting cold brooks, and possesses a strange tadpole with an enormous oral disk with which it clings to stones in swift water. *Leiopelma* is a terrestrial beast inhabiting foggy ridges or damp places, does not lay its eggs in the water, and has no free tadpole stage. There is no doubt but that the two genera are only distantly related, but also no doubt that both belong together in a very primitive family.

The distributional pattern of these frogs is now so far lost through extinction that but little can be made of it. What we know of other vertebrate distribution shows us, however, that no trans-Pacific bridge is necessary to account for the Ascaphids. The presumption would be that Ascaphids once lived in Australia, and that the ancestral New Zealand frog came from that direction, probably by way of a single chance flotation far back in geological history. While it is true that *Leiopelma* (as well as *Ascaphus*) is not well adapted to flotation, we are hardly in a position to say that its distant ancestors were not.

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[9] Two other Sundaland families, the Discoglossidae and Atelopodidae, have not done so, but these are each represented in Sundaland by single relict species. The Atelopodid is known only from Sumatra and Java (*Cacophryne borbonica*; see van Kampen, 1923, pp. 70-71, and Darlington, 1948) and the Discoglossid only from Busuanga (Myers, 1943).

Finally, I must say that the present known range of *Leiopelma* in New Zealand is very strange. While I do not know how actively these secretive frogs have been searched for in the South Island, I should not be surprised to see *Leiopelma* discovered far south of its present southernmost known station on Stephen Island. Outside of New Zealand, the Solomons, and Fiji, no native frogs are known in Oceania nor on the offshore American Pacific Islands.

7. Summary

The fish evidence indicates strongly that there has been no dry land connection of Sundaland (the islands of the Sunda Shelf, plus Mindanao and the Palawan-Calamianes chain) with the outlying islands to the east, during the Cenozoic, and probably never at all. Primary fresh-water fishes have scarcely crossed the permanent sea-barrier beyond Sundaland. Frogs of many families have crossed it in many places, at different times, and in numbers. Different families have been able to cross this and other sea-barriers with differing facility. Caecilians have not crossed it at all. Pelobatids have crossed it only northward into the Philippines; Bufonidae have not crossed it northward into the Philippines but have done so to the eastward. Ranids and to a lesser extent, some Polypedatids, have crossed this and other East Indian sea-barriers repeatedly. Hylids evidently crossed long ago, as did Leptodactylids. Frogs are plainly much more able "sweepstakes route" migrants than are primary fresh-water fishes. Frogs have been in the Solomons a long time and have even reached Fiji. Flotation and wind dispersal of amphibians across sea-barriers are discussed briefly. The New Zealand frogs are relicts of too ancient a group to make speculation on the migrations of their ancestors profitable, but these ancestors probably came from Australia by flotation. Outside the islands mentioned, no native frogs exist on the islands of Oceania nor on the offshore American islands.

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DISTRIBUTION OF THE GEKKONIDAE IN THE PACIFIC AREA

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In order to understand the distribution of the Gekkonidae in the Pacific area it is necessary to study (a) the global distribution of the family as a whole, and (b) the factors favouring distribution; but perhaps it would be better to reverse the order and consider the factors favouring distribution before global distribution, as the latter is dependent on the former.

Factors Favouring Distribution

The factors favouring a wide distribution are intimately related and are to be sought in the size, structure, habits, food, means of transport, etc. Each of these factors may be considered briefly.

Size: Gekkonids generally are of small size, the largest seldom exceeding 30 cm. in length.

Shape. Usually, the body is much depressed, the limbs short, adapted to terrestrial or scansorial life. The digits of many of the scandent species are provided with highly-specialized "adhesive" lamellae, enabling the animals to negotiate polished surfaces.

Skin. The skin is composed of tubercular or granular scales, and is completely waterproof. The last and apparently insignificant point in reality is of more importance than it appears, for, when an animal with such a covering is immersed in water it will be observed that the spaces between the scales retain pockets of air between them, and togther form a cushion of air round the body. This cushion of air lends to the buoyancy of the animal, enabling it to remain at the surface of the water almost indefinitely without exerting any effort on its part. This is an important point when we have to consider the distribution of species over wide stretches of water—this natural "lifebelt" of air enables the animal to swim more easily.

Habits. Most Gekkonids are highly camouflaged, readily emulating the colouring of their immediate surroundings, and secretive in habit. They inhabit forests or open country: under bark, stones, or in some convenient retreat, hiding by day and emerging at dusk. Many species live in houses and other human structures. They frequent goodssheds and timberyards, and are to be found hiding in many forms of merchandise. With very few exceptions Gekkonids are oviparous.

The egg-laying species usually deposit two eggs. The eggs are protected by a calcareous shell and usually are agglutinated to the surface on which they are laid. The despatch of merchandise from one point to another usually is accompanied by its quota of Gekkonids or their eggs. As loading usually is carried out by day when the lizards are in hiding there is a greater chance of the lizards being transported. Thus man inadvertently assists in the transport of these animals over long distances by land and sea.

Food. The food consists chiefly of insects and such small animals as are easily overpowered and conveniently swallowed. They are voracious feeders. During the period of activity they accumulate large reserves of fat in special "fat-bodies" when food is plentiful. Apart from these special fat-storage organs, the tail functions as an additional storage organ. The large store of reserve material enables these lizards to survive for many weeks and even months without food. This ability to survive long fasts is a definite asset to the animals, and is an important factor when considering problems of their distribution.

Usually, the period of incubation of the eggs lasts for several weeks; and it is well known that temperature will retard or accelerate the period. This point is also an advantage.

Enemies. The enemy cycle is comparatively restricted. Their secretive habits, coupled with camouflage, reduce the number of would-be enemies: birds, snakes, and other lizards form the usual cycle.

Adaptability and Variability. Although the Gekkonids are an ancient and primitive group they retain a high degree of plasticity, as is clearly evidenced by their wide distribution. They inhabit a wide range of habitats, from deserts, with high temperatures, through forests, with great humidity, to mountains in which the temperature is just sufficiently warm to maintain reptile life for at least a brief period of the year.

The high degree of plasticity is further evidenced by the extremely fluid nature of the generic and specific characters. The variability of Gekkonids is only too well-known to the taxonomist—the classification of Gekkonids constitutes a systematist's headache! Often the specific characters are so fluid that the same individual may exhibit an irregularity of scalation on the right and left sides: such individual variation makes classification and determination most difficult.

Means of Distribution. Apparently, the distribution of Gekkonids is achieved in three main ways: (a) *overland*, where no serious barriers occur; (b) *on driftwood*; (c) through *human agency* over land and sea. Overland distribution is easily understood and need not be elaborated. However, it must be remembered that narrow expanses of water cannot be regarded as serious barriers. High mountains with very low temperatures throughout the year undoubtedly would form effective obstacles.

Driftwood. Driftwood is perhaps the most important agent for dispersal in the case of Gekkonids. In tropical countries, especially where heavy rains cause widespread floods and consequent land erosion, large numbers of whole trees and logs are washed down streams and rivers with their attendant fauna. Large quantities of this debris, together with its attendant animal life, is washed far out to sea. Once at sea the drift is at the mercy of oceanic winds and currents; and it is possible that in due course the drift reaches some distant shore where the animal life "aboard" finds a new home. The driftwood may be weeks or even months at sea before it is washed up on some distant coast. The waterproof "life-jacket" of the geckos, and their ability to survive long fasts, stands them in good stead; and their adaptability enables them to survive in their new home.

It must be remembered that in the period when floods are prevalent (i.e., during the rainy season), insect life, which means food for Gekkonids, coincides with the period of feeding activity. The rain also drives them from their terrestrial hideouts, and they seek shelter on higher ground and on trees. Thus, all the factors taken conjointly assist in aiding Gekkonid distribution. Our knowledge of the course of driftwood and the length of time it is at sea, is very limited and, consequently, we can form no definite conclusions, and so forge the distributional links more solidly.

Human Agency. It is well-known that man has played a large part in the distribution of animals and plants of all kinds, either wilfully or accidentally. However, his role in the distribution of Gekkonids has been accidental: usually, they have been stowaways hidden in various forms of merchandise.

A good example of "modern" distribution through human agency is to be seen in the distribution of *Hemidactylus frenatus,* a species often confused with *H. brooki*. Both species are widely distributed in the Indian subregion, and both are commensals of man. They are found in human dwellings and storehouses, and are equally common in forest tracts, harbouring under bark and stones.

The home of the genus *Hemidactylus* undoubtedly is the Indian subregion, for, of 32 species, 17 occur in the Indian subcontinent alone. The present distribution of *H. frenatus* is widespread. The main lines of dispersal have followed an eastward course along the Asiatic continental coast, through Burma, Malaya, Siam, Indo-China, China, and as far north as Korea. This coastal distribution suggests that this gecko has been transported by coastal shipping. Further, maritime traffic from the Asiatic mainland with various islands in the Pacific evidently has been responsible for its distribution in the islands. Today it is known from Ceylon, Andamans, Sumatra, Java, Celebes, Borneo, Hainan, Formosa, Australia, Amirantes, and the Philippines. To the westward of India it has reached Mauritius, East Africa, and St. Helena! The distribution of this species is perhaps more extensive than at present recorded.

Apart from human agency driftwood, too, has contributed to the distribution of this species. However, it must be remembered that in this case we are dealing with a species which is partially a commensal of man, and that human agency alone would not account for wide distribution of non-commensal species.

Before passing to the global distribution of the family I should like to suggest one other possible means of transport of small Gekkonids, namely, the possible transport of either the animals themselves, or their eggs, when adherent to twigs collected by large birds at the time of nest building. I admit that the chances are remote, but feel that such a possibility cannot be altogether ruled out.

GLOBAL DISTRIBUTION

The family is distributed throughout the warmer regions of the world. Further, the concentration of the family is in the Oriental and Australian regions. The area of concentration of a group is believed to be an indication of the ancestral home of the group.

Although I am fully aware that much work has been done since G. A. Boulenger published his Catalogue of Lizards (1885-87), for the purpose of this paper I select this work and will analyse his findings in relation to the distribution of the Gekkonidae of the Pacific area.

Boulenger records 53 genera[1] with about 280 species. Of the 53 genera, the Australian and Ethiopian Regions each claim 20; the Oriental 16; the Palaearctic 14; the Nearctic and Neotropical 5 and 9, respectively. Again, of the 53 genera, 21 have been recorded from the Australian Region, the Pacific Islands and the continental areas bordering the Pacific Ocean. Five of the 21 are peculiar to Australia, 2 to New Caledonia, and 2 to New Zealand, thus leaving 12 genera which are spread over the remaining area.

Turning from the distribution of the family to that of the largest genus, *Gymnodactylus*, we will observe that of the 37 species described, 15 are Oriental, 10 Palaearctic, 1 Ethiopian, a total of 26 for areas connected by land or separated by very narrow stretches of water. The remaining species are distributed as follows: 5 Australian, 1 Borneo, 1 Philippines, 2 South America, and 2 from uncertain localities. How are we to account for this peculiar distribution, particularly the two South American species?

The genus *Gymnodactylus* is regarded as one of the most primitive of the family. Fifteen species occur in the Indian region. If a concentration of a group is an indication of its ancestral home, in this case India, how did two members of the genus reach far-off South America? From the geographical position of the Australian continent and the chain of islands east of the Indian region, and the trend of the oceanic winds and currents, it would not be difficult to arrive at some conclusions; but an ocean crossing over to South America is not easy to solve. However, the possibility of such an oceanic crossing cannot be ruled out altogether. It certainly is a long way from the ancestral home, apparently over an insuperable barrier, unless, of course, mere distance be discounted and the Aleutian bridge be considered.

Another strange and interesting case of distribution is that of the genus *Gonatodes*, with 18 species. Twelve of this number inhabit the Indian region. Isolated members occur in Timor, Borneo, West Indies, and 4 in South America. Noble (1921) and Smith (1933), after a careful study of the species of this genus, arrived at the conclusion that the *Gonatodes* of the Old and New Worlds probably were derived from different ancestral stock. These conclusions were based mainly on internal osteological differences, namely, the formation of the thoracic girdle and the presence or absence of postanal bones, although the external generic characters were common to both "groups". Accordingly, this genus was split into two separate genera. This would suggest a parallel development of external characters and a divergence of internal structures!

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[1] I include the *Eubleplaridae* and *Uroplatydae*.

If we are to accept the view that the area of concentration is an indication of the ancestral home of a group, then we must likewise accept that the centre of origin of *Gonatodes* is the Oriental Region. If this view is not accepted and we adopt the view that the *Gonatodes* had two separate origins, then we are faced with a much more serious problem, namely, that the Gekkonidae, as at present defined, have been derived from two separate ancestral stocks. This latter view of the origin of a single family does not appear tenable.

I give one more example of a curious distribution. If we assume that the area of concentration of a group is an indication of its ancestral home, how are we to explain the distribution of the genus *Phyllodactylus*. Members of this genus are concentrated on the Pacific side of the Americas: of 25 species, 7 are peculiar to South America and the Galapagos Islands, and 2 to California—a total of 9, or one-third of the total number in the genus. Two species are from Pacific Islands, 4 from Australia, 4 from Madagascar, 2 from Africa, 1 from the Mediterranean, and 1 from Jamaica. Thus, *Phyllodactylus* would present a reversed direction of distribution to that of *Gymnodactylus*. Again we would be faced with a problem of two or more ancestral homes for the Gekkonidae. Surely a single family cannot have arisen from more than one ancestral stock and one ancestral home! There seems to be little doubt that the family arose from a common ancestor and that its members migrated when occasions were more favourable, or were transported by various means, and that subsequently gaps have occurred in distribution which are now beyond a satisfactory explanation.

Long periods of isolation, and consequent inbreeding in restricted habitats, of such plastic creatures, undoubtedly would tend to bring about a great deviation of form and structure, both internal and external. Systematic classification has been based, and still is, on external morphology, to enable the worker to determine the species under observation. If internal anatomy were used as a basis for classification, many of the observations of the earlier workers would have to be written off as data with uncertain specific reference; such a system would require a highly specialized knowledge of comparative anatomy, and few specimens would survive the specialists, who, undoubtedly, would select different sets of characters for their individual forms of "anatomical" classification. For all practical purposes, such forms of classification would tend to defeat the very purpose of systematics. Internal structure should be subservient to morphological detail and used only as an adjunct to aid systematics based on external characters.

After this slight digression I must return to the distribution of the Gekkonids. Endemic genera constitute a real problem. In the Pacific area, excluding the continental island of Australia, we find four endemic insular genera. *Naultinus* and *Hoplodactylus* confined to New Zealand, and *Rhacodactylus* and *Eurydactylus* restricted to New Caledonia. This endemism on the one hand indicated the degree of variability possible, and on the other the great length of time that must have elapsed to enable such vast changes to come about. As I am more familiar with the two New Zealand genera I shall restrict my remarks to them.

These are the only known genera in the family that are viviparous in habit, a point indicating that they display a high degree of specialization. I am not going to attempt an explanation of their origin, nor venture a guess as to how they reached New Zealand: I do not know, but will merely refer to some points of interest.

The viviparous habit is an important departure from the general habit of the family: it entails marked changes in the internal structure, especially in the anatomy of the oviducts. In both genera the shell-secreting area is absent. The viviparous habit also has resulted in the suppression of the egg-tooth in the young. Another remarkable character apparently peculiar to them is the possession of a prehensile tail; but this character is not so well marked as in the Chamaeleonidae. Again, if we turn to *Naultinus elegans,* apart from the above-mentioned characters, there is in this lizard a further point which calls for comment, namely its colour. It is well known that, in general, Gekkonidae exhibit a changeable camouflage colouration harmonizing with the immediate surroundings. The camouflage-changes are in operation both during the day and at night. However, in *N. elegans* the colour is coupled with a change of habit, for, as far as I have been able to observe, *Naultinus* is diurnal, whereas most geckos are largely nocturnal. These, perhaps, are small details, but nevertheless, they are a marked departure from the normal characteristics of the family.

Such marked changes in external characteristics and habits undoubtedly foreshadow changes in internal structure, but without a comparative anatomical study, I am not in a position to say what awaits the student of anatomy. In the opinion of some workers, some of the above characters would be, perhaps, weighty enough to suggest that these genera arose from a separate stock from most other geckos, but I am not in favour of this view. I believe that all Gekkonidae had a common ancestry in spite of the fact that, at present, we cannot account for their great diversity of form and erratic distribution.

Dispersal of Gekkonids, it already has been suggested, could be brought about by transport on driftwood where overland passage is not possible. In the absence of any concrete evidence of land connections between the various islands in the Pacific, there appears to be no explanation of the way in which these animals could have reached their present island homes other than by oceanic drift. Their power to survive long fasts, their waterproof "life-jackets", and power of adaptability must in this case have contributed to their survival. Long periods of isolation and inbreeding, and a reduction in the enemy cycle, have tended to produce new forms and the survival of mutations which under ordinary circumstances would have been eliminated in the struggle for existence. In some instances the divergence has been so great that their nearest relatives are now difficult to trace. However, it seems reasonable to conclude that the most divergent forms were the earliest to be isolated from the remainder of the family.

NOTES ON MAMMALIAN DISTRIBUTION IN THE CAPE YORK PENINSULA

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Special interest in the Cape York Peninsula arises from the fact that it serves as the main highway of communication between the faunas of Australia and New Guinea. Further investigation of the problems posed by the region was carried out last year. The factual and numerical data presented in this brief paper are provisional, pending the preparation of detailed reports on the collections obtained in 1948 by the Archbold Cape York Expedition of the American Museum of Natural History, New York.

The mammalian fauna of the Cape York Peninsula comprises approximately: Monotremata, 2 (*Ornithorhynchus* and *Tachyglossus*); Marsupialia, 31 (Dasyuridae or marsupial cats and marsupial mice, 5; Peramelidae or bandicoots, 3; Phalangeridae or possums and other allies, 13; Macropodidae or kangaroos and wallabies, 10); Rodentia, Muridae or native rats and native mice, more than 10; Chiroptera, ± 30 (Megachiroptera or flying foxes and fruit bats, ± 8; Microchiroptera or insectivorous bats, ± 22). Total, ± 73 full species.

Because the patterns of distribution of the 30 bats are so imperfectly known these flying mammals have been excluded from present consideration. The aquatic genera *Ornithorhynchus* and *Hydromys*, the distribution of which is greatly influenced by the fluvial pattern of the country, have also been left aside. Only the 41 or more terrestrial and scansorial mammals have been used as the basis of the remarks which follow.

Before examining the distributional patterns of the mammals of the Cape York Peninsula further, a short description of the general environment is offered. The Cape York Peninsula may be delimited from the main mass of Australia by a line drawn from the southernmost shore line of the Gulf of Carpentaria eastward to the Pacific coast. This definition is arbitrary and conforms to no geological or biogeographical boundary. Thus, the peninsula so described includes the northern part of Atherton Tableland. Roughly triangular, it has two long sides converging northwards to Cape York proper and stands on a shorter base—the east-west line described above. Its length from south to north is approximately 500 miles. Its width at the base may be taken as 400 miles. It lies between s. lat. 11° and s. lat. 17°.

The physiography of Cape York Peninsula, sketched in broad terms, centres on a north-south divide placed relatively close to the eastern side, the eastern run-off of which is short and steep, the western slope very long and forming an almost imperceptible gradient to the Gulf of Carpentaria. The main drainage systems consequently flow to the west, while to the east, rivers are comparatively small and rapid. The divide at the northern tip of the Peninsula reaches altitudes of only 200 to 300 feet, but becomes gradually higher in the south, attaining to peaks from 3000 to 5000 feet. This Peninsular divide becomes increasingly complicated by the presence of lateral ranges and spurs. Many of the highest peaks stand on these side ranges instead of on the Great Dividing Range itself.

The climate of the Peninsula is monsoonal. During the period when the heat equator is north of the true equator (April to October) the "dry season" is generally effective, though, as elsewhere in the tropics, there exists a lag both in the onset of the "dry" and in its termination. However, by May the south-east trade wind controls the climate, dropping whatever moisture it carries when it reaches the mountains of the east coast and continuing across the Peninsula as a dry, though sometimes cloud-bearing wind.

Though the heat equator moves south of the true equator during late September, the above-mentioned lag—perhaps occasioned by the momentum of the "south-east"—often prolongs the dry season into October and November. By late November, when the doldrums have passed still farther to the south, the effect of the rain-bearing north-east trade wind, modified south of the equator into the "north-west", is felt as a series of storms which herald the wet season in the northern parts of the Peninsula. The rains spread week by week farther south. Again the aforementioned lag operates, so that the "wet" may extend well into April. Actually the transition is far from uniform and may be complicated by cyclic weather phenomena, including hurricanes. Generally the rivers run full and the great western plains receive copious rain from December to April, whereas from May to November rivers dry up and rain seldom falls west of the main divide.

Temperatures are generally fairly uniform—tropical at the northern tip. The coastal strip near the base of the Peninsula in "winter" (July-August) becomes agreeably cool, while in the dry interior—the western side of the Atherton Tableland as far as Normanton—the temperature sometimes falls to freezing just before sunrise. Some 30 miles south of Cooktown, at Shipton's Flat, 800 feet above sea-level the 6 a.m. temperatures in September fell almost to 50°.

The geology of such an enormous area as the Cape York Peninsula can scarcely be touched upon in this article. Very large portions of the region are granite; other extensive portions are sandstone. The "mineral belt"—chiefly in the mountainous parts—is composed of greatly deformed sediments bearing valuable ores of iron, tin, gold, and wolfram. In the south-west are extensive deposits of limestone as well as great sheets of basalt covering many square miles of country. By decomposition these rocks have produced a variety of soils, which are further modified by climatic factors into sands, clays, mucks, etc.

The geology and the climate of the Peninsula primarily control its vegetation. In the broadest sense there are but two main classes of vegetable cover: "open forest" and "rain forest". Both have numerous subdivisions. Open forest, which covers most of the Peninsula, is found chiefly in areas where a pronounced water shortage exists for a number of months of the year. But it is also found locally in areas of ample rainfall. Its constitution varies widely: iron-bark forest, she-oak forest, stringy-bark and messmate forest, bloodwood forest, wattle forest, pandanus forest, even palm forest—depending upon the dominant types of trees. But most of those kinds of open forest agree in certain features: the trees are widely spaced, tall or short, with grey-green foliage throwing little shade. There is little or no undergrowth; coarse grasses grow beneath the trees; the intense light of the sun reaches the very roots of the grasses. Open forest, unfortunately, is easily set on fire and each year hundreds of miles of it are burned over in the name of the cattle industry; dormant grasses in this way are given a "shot in the arm" and put forth green sprouts somewhat in advance of the grassplants of unburned areas. At the same time all humus is destroyed, as well as most of the older weaker trees and fallen hollow logs which may afford cover to animals. This "ocean" of open forest surrounds the "islands" of rain forest and isolates them from one another.

Rain forest depends for its continuance upon water, whether aerial or seepage. It occurs where enough water is present through most of the year. It comprises mainly broad-leaved trees which form dense shade. In it vines and epiphytes are plentiful. It grows in varied form on stony hillsides, well-drained flats, or old flood plains margining rivers. It generally forms narrow belts on the east-facing slopes of the ranges from 10 to 25 miles in width, though as much as 100 miles in length. Only the combination of nutritious soil and adequately distributed rainfall will allow full development of these rich tropical jungles, which must not be confused with flood-plain forests, covered in the wet months by 10 or 15 feet of water, or with mangrove forests. Both the latter, though they may also receive copious rain, obtain much of their water by seepage. Rain forest is sometimes found continuous with flood forest or mangrove forest, the one type changing gradually or abruptly into the other. Its larger masses are important both as the nurseries of Australian timbers and because they act as reservoirs for the rich variety of animal life requiring their shelter.

The Cape York rain forests do not, as one may suppose, form a continuous band along the north-south ranges, but are parted into several distinct masses or "islands" by stretches of open forest. The largest and most important "island" is the Innisfail-Cairns-Cooktown mass at the eastern side of the base of the Peninsula, which partly covers the Atherton Tableland and includes the great mountains Bartle Frère and Bellenden Ker. The second and less well-known is the Rocky Scrub-Iron Range mass. Separated from the first by 150 miles of open forest, it is nearly continuous for about 100 miles north and south, while its width varies from 5 to 10 miles. Both of these big "scrubs" are the homes of important and distinct species of animals. At the extreme tip of the Peninsula there are scattered patches of rain forest, isolated from one another by narrow belts of open forest, which shelter a depauperized remnant of the Iron Range fauna. The intervening area—east and south-east of the Jardine River, though poorly known, seems also to contain scattered patches of rain forest.

Throughout the eastern side of the Peninsula one observes the interfingering and the mosaic patterns made by open forest and rain forest. These irregular pictures can perhaps be explained on edaphic grounds. Besides the two primary types of vegetation just indicated there occur here and there heath-like areas, including the ill-defined "turkey brush"; also swamps, sand dunes, rock outcrops, and mangroves. Most of them are strongly illuminated and without shade.

Most of the non-volant mammals existing in the Peninsula inhabit either the open forest or the rain forest, locally termed "scrub". A very few, such as *Tachyglossus* (of Australian origin), the aquatic *Hydromys* (of ancient Papuan origin), and *Ornithorhynchus* (also Australian) appear to be equally at home in either. *Dactylopsila,* the striped possum, too, is found almost as often in open forest as in rain forest, though if one may judge by its New Guinea origin it probably belongs to the rain forest assemblage.

The species of the uninterrupted open forest have extensive ranges. There appear to be few if any definable barriers limiting the spread of such species. Where such limiting factors seem to occur—as in the case of the northward limits of *Macropus, Petrogale, Trichosurus, Mesembriomys* and *Leggadina* near Wenlock, about s. lat. 13°, the controlling influences are certainly obscure and possibly complex. Also there is no certainty that the distributional limits of these mammals occur at the same place. The factors which limit any one of these mammals may have little to do with the factors limiting others.

The open forest mammal fauna of Cape York Peninsula comprises about 20 species, of which seven are definitely arboreal and most hide by day in holes in trees. Of the 13 remaining, 11 are definitely terrestrial while two are good climbers. With the exception of *Melomys lutillus* and *Satanellus hallucatus,* all are positively Australian. *Melomys lutillus* is an open country-inhabiting species of a New Guinea rain forest genus. *Satanellus hallucatus* occurs in Australia chiefly north of s. lat. 20°, except in the south-east of its range, where it has been taken at Yeppoon near Rockampton and at Clermont. Though its nearest relative is S. *albopunctatus,* a rain forest species of New Guinea, it is wholly Australian from the generic standpoint.

Of the seven arboreal open forest species, two (*Petaurus australis* and *Phascolarctos*) have not been found north of the latitude of Cooktown; one (*Pseudocheirus peregrinus*) reaches its northern limit near Coen; two (*Trichosurus* and *Mesembriomys*) extend little beyond Wenlock; one (*Acrobates*) attains the tip of Cape York, and one (*Petaurus breviceps*) extends across the Torres Straits to many parts of New Guinea.

Seven of the 11 terrestrial open forest species are Macropodidae (*Petrogale, Aepyprymnus rufescens, Macropus canguru* and *robustus, Protemnodon parryi, bicolor,* and *agilis*); one (*Isoödon*) is a bandicoot; one (*Sminthopsis aruensis*) is a marsupial mouse; two (*Rattus culmorum, Leggadina*) are rodents. Three of the Macropodidae (*A. rufescens, P. parryi, P. bicolor*) reach their northward limits near Cooktown, three (*Petrogale, M. canguru, M. robustus*) near Wenlock, and one (the sand wallaby, *Protemnodon agilis*) crosses into the grass country of south New Guinea. The *Sminthopsis,* the *Isoödon* and one of the rodents, *Rattus culmorum,* have substantially the same range in New Guinea as the sand wallaby. The other rodent, *Leggadina,* extends north only to Wenlock. The ubiquitous *Tachyglossus,* it should be added, is also at home north of the Torres Straits in the same area as the sand wallaby.

The mammals inhabiting the Cape York Peninsula rain forests present markedly different dispersal patterns. At least 21 species occur. Of those about half can be classed as truly Australian and half as truly Papuan. *Antechinus, Dasyurops, Perameles, Eudromicia, Pseudocheirus herbertensis* and *P. lemuroides, Hypsiprymnodon, Thylogale stigmatica, Protemnodon bicolor* are Australian. *Echimypera, Dactylopsila, Phalanger orientalis* and *P. maculatus, Pseudocheirus* (*Pseudochirops*) *archeri, Dendrolagus bennettianus* and *D. lumholtzi, Rattus leucopus* and *R. conatus* (possibly conspecific), all the arboreal *Melomys,* and *Uromys* are Papuan.

Of the truly Australian rain forest species *Pseudocheirus herbertensis* and *P. lemuroides, Hypsiprymnodon,* and *Protemnodon bicolor* (rare) stop their northward spread near Cooktown. *Perameles* has reached the McIlwraith rain forests east of Coen. *Dasyurops gracilis* is probably also there but the evidence is inconclusive. The genus *Antechinus,* widely spread both in Australia and in the mountains of New Guinea, is represented in the McIlwraith scrubs east of Coen and at the Iron Range but was not discovered in the rain forests at the "tip".

The dormouse phalanger *Eudromicia* is found in the Innisfail-Cooktown rain forest but is not recorded farther north on the Cape. On the other hand it is well distributed in New Guinea. The genus *Eudromicia* is here held to be Australian because of the presence of the very closely related *Cercartetus* in the southern parts of Australia and in Tasmania. *Thylogale stigmatica* alone of the Australian rain forest species extends to the tip of the Cape and across into the lowland scrubs of south New Guinea.

The dispersal southwards of the New Guinea rain forest species, all of which are arboreal except *Echimypera, Rattus,* and *Melomys lutillus,* presents several differing patterns. On the one hand the mainly arboreal genus *Melomys,* represented by several local "species", is found almost continuously along the humid coastal strip as far south as northern New South Wales. The *Rattus leucopus-conatus-assimilis* group displays a generally similar pattern. The other Papuan invaders of Australia, if not halted farther north, appear to have been stopped in their southward movements by the great open forest break at Townsville and the lower Burdekin River area. Thus far south have advanced *Dactylopsila, Pseudocheirus* (*Pseudochirops*) *archeri, Dendrolagus lumholtzi* and *Uromys.* Negative evidence suggests that *Pseudochirops* and *Dendrolagus,* having passed through the scrubs of the "tip", Iron Range, and the McIlwraith Range, died out in those intervening sets of rain forest. *Dactylopsila* and *Uromys* on the contrary were found in 1948 in all the large areas of rain forest. The tree-climbing kangaroo, *Dendrolagus bennettianus,* though it reached the northern side of the Innisfail-Cooktown rain forest, seems not to have spread much south of the Daintree River—not to have reached the latitude of Cairns.

The remainder of the New Guinea rain forest species, *Echimypera, Phalanger orientalis* and *Phalanger maculatus* were stopped at the southern edge of the Iron Range-McIlwraith Range rain forests, probably by the great 150-mile stretch of open forest between there and Cooktown. Of those species, only *P. maculatus* can now be found in the forests at the "tip". The *Echimypera,* newly described, is known only from Rocky Scrub on the McIlwraith Range in the latitude of Coen.

The absence of so many Papuan mammals from the rain forests through which they must once have passed in order to enter their present habitats probably indicates past changes of those environments. The successive passages of the tree kangaroos to the Innisfail-Cooktown rain forests and of the phalangers to but not beyond the Iron Range-Rocky Scrub forests favours the view that more than one wave of invasion took place. The changes of environment may have been fairly extensive, for the alterations in ocean level generally held by geologists to have taken place synchronously with the Pleistocene glaciations, coupled with the slightly cooler world temperatures of that time may have had important repercussions on local climates. Slightly increased or prolonged rainfall may have partly closed some of the gaps between present rain forest islands.

To summarize in conclusion: The extensive open forest west of the Peninsular divide has permitted appropriate Australian species to push towards or into New Guinea with varying degrees of success. The interrupted strip of rain forest along the eastern slopes of the divide or its outliers has likewise allowed the southward spread of the rain forest haunting species of New Guinea. The total number of Australian mammals which have invaded New Guinea is eight. Only one of these (*Petaurus breviceps*) is arboreal. Only one (*Thylogale stigmatica*) lives in rain forest. The total number of New Guinea mammals which have invaded Australia is eleven (actually more because I am treating the arboreal *Melomys* provisionally as a single unit). Of these, all but two groups, *Rattus leucopus* and allies, and *Echimypera*, are arboreal. It would seem then that Australian terrestrial open forest mammals and New Guinea arboreal rain forest mammals are the most successful colonizers into essentially favourable environments. Such invasions have probably not taken place at once but at different periods of late Tertiary history.

PALEOGEOGRAPHICAL SIGNIFICANCE OF FRESH-WATER FISH DISTRIBUTION IN THE PACIFIC

By George Sprague Myers, Stanford University

1. Introduction

In a paper published over a decade ago, I said that zoogeographers, like Gaul, are divided into three parts—those who build bridges, those who do not, and the proponents of continental drift. This is still true, but it may be remarked that the thinning ranks of the bridge-builders and the drifters are today almost deserted by the zoologists. Some of the old-time botanists still stoutly man the Wegenerian or Gregorian ramparts, and conduct isolated sorties for the glory of drift or a foundered Pacific continent, but they are scarcely aware of the strength mustered against them.[1] My purpose is to fire one more gun against these besieged garrisons, and, at the same time, to point out what modern fresh-water fish evidence appears to indicate in regard to the history of Pacific island groups.

Only recently have fresh-water fishes come into their own in interpreting continental zoogeography. In the time of Darwin and Wallace they were too little known to be of great importance, and most of the main strokes in the zoogeographical picture were painted from the evidence of mammals and birds. Eigenmann (1909) and Regan (1922) were the pioneers in modern ichthyological geography, but their belief in a great late Cretaceous South Atlantic land bridge, like that of others in a great Pacific continent, has gradually been discarded, simply because it creates far more problems than it solves.

In regard to such bridges, I wish to quote from a rather well-known naturalist, as follows:

"Ingenious men will readily advance plausible arguments to support whatever theory they shall choose to maintain; but then the misfortune is, every one's hypothesis is each as good as another's, since they are all founded on conjecture. The later writers of this sort, in whom may be seen all the arguments of those that have gone before . . . stock America from the western coast of Africa . . . and then break down the Isthmus that bridged over the Atlantic. But this is making use of a violent piece of machinery; it is difficulty worthy of the interposition of a god! '*Incredulus odi*'."

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[1] See especially Matthew, 1915; Noble, 1925; Dunn, 1931; Schmidt, 1943; Simpson, 1939, 1940, 1941; Darlington, 1948; Berry, 1928; Chaney, 1940.

Some of you may recognize the quotation. It occurs in a letter to Thomas Pennant, written by Gilbert White, at Selborne, May 29th, 1769. Vast continental land bridges have been opposed by some naturalists for a long time!

As recently as 1938, I pointed out for the first time that the so-called true fresh-water fishes, which alone have been recognized as good evidence in terrestrial zoogeography, really consist of two groups, a primary one composed of fish families sharply restricted to fresh water, and a secondary of families which apparently are able to cross short ocean barriers. The primary fresh-water fishes were shown to be sharply restricted to the continents, whilst the secondary alone have been able to reach the Greater Antilles, Madagascar, and other peripheral areas. In 1948, Dr. Darlington gave an excellent resumé of the world's fresh-water fish distribution, in which he expanded the fish data given in my 1938 paper, and included amphibians and reptiles. Darlington gave only brief attention to the Pacific island faunas, but a familiarity with his paper is useful in interpreting fresh-water fish distribution. If we add some interesting discussions by Nichols (listed by Darlington, 1948), this completes the main recent history of general fresh-water fish geography, unless one wishes to include such compilations as those of Meek (1916), Kyle (1926), MacFarlane (1923), Scheuring (1929, 1930), and Arldt (1938). The last is, I believe, the most ponderous existing example of the way biogeography should *not* be done.

2. Fresh-water Fishes

The fishes of fresh waters may be classified zoogeographically in the following groups (Myers, 1938, 1949):

(1) *Primary*. Strictly intolerant of salt sea water. (Existing Dipnoi, Polypteridae, Osteoglossidae, Cyprinidae, Characidae; most families of siluroids; Centrarchidae, Percidae, etc. There are a few exceptions in these groups, but they are exceedingly few.)

(2) *Secondary*. Rather strictly confined to fresh water but evidently capable of occasionally crossing narrow sea-barriers; tolerance of sea water for short periods known for many. (Lepisosteidae; most Cyprinodontidae, Poeciliidae and Cichlidae; Synbranchidae, etc.)

(3) *Diadromous*. Fishes which regularly migrate between fresh and salt water at a definite period of the life cycle. (Sea-lampreys, *Alosa, Oncorhynchus, Galaxias, Anguilla, Sicydium,* etc., etc.)

(4) *Vicarious*. Presumably non-diadromous fresh-water representatives of partly or primarily marine groups. (*Siniperca; Lota; Plagioscion;* fresh-water Ariidae, Plotosidae, Apogonidae, Atherinidae, and Syngnathidae; landlocked or non-diadromous Galaxiidae; etc.)

(5) *Complementary*. Fresh-water fishes, often or usually diadromous and belonging to marine groups which become dominant in fresh water only in the paucity or absence of primary, secondary, and probably also vicarious fresh-water faunas. (*Agonostomus, Joturus, Cestraeus, Sicydium, Sicyopterus, Stiphondon,* certain New World Gobiesocidae, etc.)

(6) *Sporadic.* Fishes which live and breed indifferently in salt or fresh water or which enter fresh water only sporadically and not as a part of a true migration. (Many Lutianidae and Sciaenidae; probably many Mugilidae; *Gasterosteus, Mollienisia,* etc.)

The continental fish faunas of the world are composed principally of primary fresh-water fishes, and most of the remainder are secondary fresh-water fishes. The families of the primary group appear mostly to have had a long fresh-water history, extending back to the Eocene, and their physiological intolerance of sea water seems to be deep-seated (Myers, 1938).

True fresh-water fishes seldom cross ocean barriers; those of the primary group almost never do but the secondary ones appear to have done so on several occasions. Fishes of the vicarious group may often be able to make such crossings, since most of them appear to be of relatively recent derivation from marine types. If they are purely fresh-water residents of relatively long standing, they may show geographical relationships between lands now separated by the sea. But each instance of this type must be closely judged on its own merits. Diadromous, complementary and sporadic fresh-water fishes seldom are of any particular importance in showing terrestrial geographical relationships.

3. INDO-AUSTRALIAN ARCHIPELAGO

This term is used here to indicate the entire region from Sumatra and the Philippines to and including Australia. Relationships within this archipelago inescapably involve Wallace's and Weber's Lines and these have been ably discussed by Mayr (1944). His fish data are mostly from de Beaufort (1913 and 1926) and are thus somewhat outdated. In addition he has misinterpreted some ichthyological facts and not realized the importance of others.

Makassar Strait forms the most spectacular zoogeographical boundary to be found among the world's fresh-water fish faunas. To the west lies Borneo, teeming with 17 families and 300 or more species of primary fresh-water fishes. Only 85 miles to the east lies Celebes, with two solitary species of primary fresh-water fishes,[2] both probably introduced by man. Celebes, like Borneo, has a few secondary forms (Cyprinodonts and a Synbranchid), as well as a peculiar small group of vicarious Atherinidae, but the difference from the magnificent Bornean fish fauna is very close to awe inspiring.

South of Makassar Strait, Wallace's Line is not quite so spectacular, since the primary fresh-water fish fauna of West Java is much smaller than that of Borneo, whilst that of East Java and Bali seems to be impoverished. Comparing Java as a whole with Lombok, Sumbawa and Flores, we find 12 families and nearly 100 species of primary fresh-water fishes immediately to the west of Wallace's Line (data mostly from Dammerman, 1929) and but four families and five species of primary fresh-water fishes to the east of it (de Beaufort, 1913). Of these five, at least three have probably been carried across by man as food fishes,[3] and it is notable that two of them are the same species that have crossed Makassar Strait. The remaining two primary species which have crossed to the east of Lombok Strait are small fishes of two Cyprinid genera (*Rasbora* and *Puntius*) which perhaps have crossed sea-barriers elsewhere.[4]

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[2] *Anabas testudineus* and *Ophicephalus striatus.* Both are commonly carried about alive by man as food fishes, the latter more than the former. *Anabas* is said occasionally to enter brackish water.

The Philippines deserve especial mention. (See Herre, 1924a, 1942b.) Bornean primary fresh-water fishes exist in Palawan and the Calamianes Islands, which are on the Bornean continental shelf and are, zoologically, completely Bornean in affinity. One species (*Puntius*) has gotten from the Calamianes to Mindoro. The continental shelf appears to break down to some extent along the Sula Archipelago, but three genera (including *Rasbora* and *Puntius* again) have gotten a foothold in Mindanao, and two or three races or poorly differentiated species of each occur in different parts of the island. In Lake Lanao, located in central Mindanao, *Puntius binotatus* (the same species which crossed Lombok Strait from Bali) has flowered into a most remarkable lake fish-fauna, several species of which are so peculiar as to have been placed in different genera (Herre, 1924, 1933). I intend to take up the evolutionary problem of the Lanao fish fauna in another place. Finally, Mindanao possesses an endemic Clariid catfish, but some Clariids do enter brackish water, according to Weber and de Beaufort (1913) and Dammerman (1929).

All of the islands between the Sunda continental shelf and the Australian-New Guinean continental shelf, including all of the Philippines except Mindanao and the Palawan-Calamianes group, form an ichthyological no-man's land, so far as primary fresh-water fishes go. Three common Sundaland species belonging to primary groups are widely spread over many of these islands—*Clarias batrachus, Ophicephalus striatus,* and *Anabas scandens*—but all three are air-breathing foodfishes often carried about alive in the Orient, especially the *Ophicephalus,* and the other two are reported to enter brackish water. Two or three more *Clarias* also occur in the Philippines but some enter brackish water. Other primary fishes have entered this no-man's land, apparently by non-human agency, only at Mindoro (1 species), and at Lombok (2 species). In both instances the same genus (*Puntius*) is concerned, in addition to *Rasbora* in Lombok. When one considers the 17 or 18 families and 400 or more species of primary fresh-water fishes of Sundaland, Wallace's Line (essentially the edge of the Asiatic continental shelf) stands out as a great major faunal boundary of excessive sharpness.

Perhaps the most interesting thing about it is the other Asiatic vertebrates, even amphibians, show no such strict limitation to the Sunda Shelf as do the primary fresh-water fishes (Mayr, 1944). These fishes are able to migrate slowly across any well-watered land. But only a very small number of species of any primary fresh-water fish fauna seem able to cross a salt-water barrier of any description. If Sundaland had been connected with the islands to the eastward at any time since the Eocene, primary fresh-water fishes of some type should swarm in the islands to the east of Wallace's Line. That they do so only in Mindanao proves to my entire satisfaction that there has been no land connection except with Mindanao. Moreover, if it proves that, it also proves that other vertebrates, including amphibians, can and do cross sea-barriers with relative ease, however they may do it.

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[3] The three are *Anabas testudineus, Ophicephalus striatus*, and *Clarias battrachus.* Both the first and the last are said occasionally to enter brackish water.

[4] Holly (1927) has recorded 11 species of primary fresh-water fishes from the ichthyologically little known island of Sumba (Sundalwood), south-east of Sumbawa and Lombok. The species are all found in Borneo, Banka, and Sumatra, and four of them (*Rasbora kalochroma, Ophicephalus melanosoma, O. bankanensis*, and *Betta anabatoides*) are unknown in Java. Some mistake in the locality must have occurred, and I suggest that Holly's whole collection came from somewhere in Borneo or Sumatra.

Weber's Line, as Mayr (1944) shows, is a line of faunal balance. From the fresh-water evidence, the Australian-New Guinea continental shelf, including the Aru Islands but excluding Halmaheira, Ceram and Timor, is a more significant line. This shelf marks the westward limits of the Melanotaeniin fishes (Regan, 1914; Weber and de Beaufort, 1922), which are perhaps the most generally characteristic of Australian fresh-water fishes. Although the Melanotaeniins are only vicarious fresh-water forms, belonging to the primarily marine family Atherinidae, and are said by Regan (1914) not to be of much importance in terrestrial zoogeography, it is very suggestive to note their absence from Ceram and Halmaheira, where so many vicarious or diadromous Papuan species are to be found.

Australia and New Guinea possess only two species of primary fresh-water fishes, the Queensland Ceratodontid lungfish (*Neoceratodus*) and an Osteoglossid, *Scleropages leichardtii*, common in Queensland and once recorded from New Guinea on the basis of a photograph.[5] Both are solitary relict forms, whose ancestors got to Australia previous to the Cenozoic, probably at about the time Marsupials entered that continent. The lungfish has no close living relative. The *Scleropages* has as its only close living relative another species (*S. formosus*) found from Siam and Indo-China to Borneo. Three other living Osteoglossid species exist in Africa and South America, but the family has a still wider Eocene distribution (Myers, 1938). That these ancient fishes, although considered primary fresh-water forms today, may have had close relatives capable of crossing sea-barriers, is entirely possible. Indeed, it would seem probable that they did, for if Australia (and New Guinea) had been connected by a dry-land bridge with Asia during the Mesozoic, Australia should be a veritable living museum of Mesozoic types of fresh-water fishes. That only two such species exist in a continent whose fresh-water fish fauna is notably depauperate, and in which there has, therefore, been less competition than elsewhere, points to the conclusion that neither Australia and New Guinea, nor any of the other islands east of Sunda Shelf, have ever had wide open dry-land connection with Asia. This is directly in line with Simpson's conclusion (1940, pp. 156-157) that the mammal colonizers of Australia reached that continent from Asia by what he terms a "sweepstakes" or "island hopping" route across one or more sea-barriers.

All the rest of the comparatively depauperate Australian-New Guinean fresh-water fauna is composed of secondary fresh-water fishes (very few, such as *Synbranchus bengalensis,* see Regan, 1914), of vicarious representatives of marine groups, and of a few strange diadromous families such as the Galaxiids.

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[5] Mayr (1944) thus had no basis at all for stating that the absence of primary fresh-water fishes of Seran (Ceram) and Kei indicates that these islands have had no continental connection with New Guinea. Fowler (1941) recognizes two Queensland species of *Scleropages*, but *S. guntheri* is a very doubtful species.

Except for the two relict primary species, Australia and New Guinea have no true fresh-water fishes. Any paleogeographical conclusions to be gained from the rest of the fresh-water fish fauna is, therefore, open to question simply because of the presumption that most or all of the species either can or do enter the sea with impunity. Iredale and Whitley (1938) and, more recently, Whitley (1947), have delimited distinctive Australian fluvial regions based on fresh-water mollusks and fishes, but so far as the fishes are concerned, it would appear that these regions may be as much reflections of the marine faunal composition on the adjacent coasts as they are anything else. In any event, comparatively little as yet on record regarding the possible seagoing abilities of most of the Australian and Papuan vicarious fresh-water fishes.

4. New Zealand

New Zealand has no primary or even secondary fresh-water fishes and there is, therefore, nothing in the fish evidence upon which to base any positive opinion in regard to its former connection with Australia or any other land mass. However, that New Zealand does not have either primary or secondary true fresh-water fishes, as it should have if it has been connected to Australia or especially to South America (directly or via Antarctica) during the Cretaceous or early Cenozoic, indicates that any continental connection it may have had must have been rather far back in the Mesozoic.

That the Galaxiids indicate any connection is very doubtful, in spite of their peculiar distribution (South Africa, South Australia, New Caledonia, New Zealand, Southern South America). Regan (1906) pointed out that some forms, at least, are catadromous, and Scott (1941) shows that at least one Tasmanian species enters the sea. Hefford (quoted from Phillipps, 1940) describes the breeding of *Galaxias attenuatus,* which appears to have tide-controlled spawning habits similar in some ways to those of the California grunion, an Atherinid. That the young of some forms are found at sea is established, and it is probable that marine wandering is the key to the family's distribution.

5. Formosa and Japan

There has never been much question but that the main islands of Japan were connected with the mainland at no very distant time, geologically speaking, and the fishes demonstrate this. The large primary fresh-water fish fauna of Formosa is practically identical with that of adjacent Fukien on the Chinese mainland, but not with that of Japan, and any apparently endemic species and genera should be accepted with caution until Fukien is more extensively fished. But Formosan relationship with the Luzon fauna, which appears in some terrestrial groups, is totally absent in the primary fresh-water fishes, simply because the Northern Philippines have not and apparently never had a native primary fresh-water fish fauna. *Ophicephalus striatus, Anabas,* and *Clarias* are there, undoubtedly introduced by man, but nothing else except one or two secondary fishes. It may be that secondary or other fishes have gotten to Formosa from Luzon, by means of typhoon winds, but the fact that the species are also found on the mainland makes this difficult to determine. The Riu Kius have a very few fresh-water fishes, mostly Formosan species, and perhaps had a fairly recent but tenuous connection with that island.

6. OCEANIA

The islands of Oceania have not a single primary or secondary fresh-water fish except for recent introductions by man. The nearest thing to a native fresh-water fish anywhere is a Galaxiid on New Caledonia (Weber and de Beaufort, 1915; Scott, 1936), which could have gotten there by sea from Australia. If there had been any great continental land mass in the Pacific during any part of the Cenozoic it should have had primary or secondary fishes, or at least have evolved some recognizable, peculiar, vicarious fresh-water types. That no such types are evident on a single island of Oceania should of itself dispose of the notion of any such continental mass as J. W. Gregory (1930) postulated.

The fishes which occur in the fresh waters of the islands of Oceania are well illustrated by Weber and de Beaufort's list of New Caledonian fishes (1915). There are diadromous fishes such as *Anguilla*, some of the gobies, and the Mugilidae, and there are sporadic fresh-water fishes such as *Kuhlia*, *Ambassis*, *Lutianus* and some other gobies, but nothing more. Complementary fresh-water fishes, such as *Sicyopterus*, *Stiphodon*, and *Cestraeus*, are dominant.

7. THE GALAPAGOS

This is the only group of islands on the American side of the Pacific which are of a size and distance from the mainland sufficient to make their inclusion necessary. There is only a single fresh-water stream of consequence in the entire Archipelago. It is on Chatham Island (Watering Bay) and I have fished in it. It appears to contain but one species, *Agonostomus hancocki* (Seale, 1932), a diadromous, complementary fish related to American mainland forms and perhaps not specifically separable. Since Dr. Hubbs tells me he has gotten young *Agonostomus* in the sea at Acapulco, this fish has no direct bearing on the origin of the Galapagos fauna.

8. SEA CROSSINGS BY PRIMARY FRESH-WATER FISHES

The few primary fresh-water fishes which are presumed to have crossed ocean barriers between Pacific islands by other than human agency are confined chiefly to three genera of Cyprinidae and to three points of crossing. One *Puntius* (an endemic species) exists in Mindoro; its ancestors certainly came via the Calamianes group. Three genera (*Puntius*, *Rasbora*, *Nematalestes*) have reached Mindanao from North Borneo, apparently via the Sulu chain. One *Puntius* and one *Rasbora* have reached Lombok and Sumbawa from Bali or Java, but whether they have recognizably differentiated on the different islands has not been adequately ascertained.

The Mindoro and Lombok crossings involve one and two species respectively. The species are small and common. The Lombok fishes may have been carried across by man, especially Chinese, who like to transport small live fishes, but I doubt it. The Mindoro species is endemic, is not found in the well-fished Calamianes Islands, and was not carried by man. There may be more than one species in poorly-fished Mindoro.

The Mindanao crossing is more complicated. *Puntius binotatus*, a a widely-distributed species in Sundaland and the same one that made the Lombok crossing, must have gotten across at least as far back as the early Quaternary, for from it evolved the recent but rich fauna of closely-related forms in Lake Lanao (Herre, 1924; 1933).[9] Two or three other races or species of *Puntius* are also found in Mindanao streams, but these are all close to or inseparable from *P. binotatus*. Two forms of *Nematabramis* are known from Mindanao (Herre, 1924). They may not be really different and one at least is identical with a North Borneo species. The two Mindanao *Rasbora* are close to Bornean forms. Apparently *Rasbora*, *Puntius* and *Nematabramis* are found on several of the Sula Islands, from Basilan to Tawitawi.

Various writers (see especially Matthew) have pointed out that smaller terrestrial animals undoubtedly have been transported across sea-barriers on rafts of jungle vegetation which float out of tropical rivers during periods of flood. I have seen such rafts myself—even one supporting a ten-foot boa-constrictor! But fresh-water fishes do not cross seas on rafts.

Darlington (1938) has searchingly discussed this and other methods of over-water dispersal, especially by winds and storms. It is now perfectly well authenticated that waterspouts caused by tornadoes can and do occasionally pick up small fishes and deposit them at a distance (Gudger, 1929a; 1929b). Mindoro and the Calamianes are in the typhoon area, which could easily explain the single *Puntius* in Mindoro. Lombok and Sumbawa are not in a typhoon area. But waterspouts do occur in many places and they do pick up fishes and upon rare occasions carry them for short distances. The distances involved here are comparatively short. We do not know anything about the specific salt-tolerance of the two species concerned, but if they could not have navigated a short stretch of salt water and were not introduced into Lombok and Sumbawa by man, there are only two ways they might have crossed Lombok Strait—by waterspout or (as suggested by Mayr) upon a sheet of fresh surface water during heavy rains. Lombok Strait was evidently much narrower (and Lombok and Sumbawa one island) during the Pleistocene. Crossing would have been easier under such conditions. In any event I do not think these two fishes present much of a problem.

Darlington (1948, pp. 7-8) has presumed that the Cyprinids had to cross sea-barriers to reach both the Palawan-Calamianes group and Mindanao. I think this very unlikely for the former. Palawan and even Busuanga have too many species (not only of fishes) in common with North Borneo, and a land connection seems certain.

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[9] Dr. Bailey Willis tells me that the lava which dams Lake Lanao is probably not over 10,000 years old, and the lake was formed by this lava dam. The fauna is no older than the dam, in any event.

Tentatively, I have previously agreed with Darlington that there was no recent dry land connection of Mindanao with Borneo, but this conclusion appears to be untenable upon careful study. The three genera which reached Mindanao still exist on the larger Sulu islands, and it is wholly possible that faulting has recently deepened some of the inter-island channels, which are still all fairly shallow. The North Borneo fresh-water fish fauna is notably depauperate, compared to South Borneo, and a dry isthmian link along the Sulu chain in the Pleistocene would have freely allowed to cross just the fish which did.[7] It is, therefore, my opinion that the Mindanao fresh-water fishes arrived via a dry Sulu land bridge, and certainly not earlier than the Pliocene.

9. Conclusions

There is nothing in the distribution of the fresh-water fishes of the Pacific islands favourable either to continental drift or to J. W. Gregory's Pacific continent, and much that opposes the latter. In fact, the fish evidence points directly to the conclusion that the islands of Oceania are truly oceanic, in the sense of Wallace.

In the great Indo-Australian Archipelago, the fish evidence very strongly supports the conclusion that there has been no dry land connection whatsoever between the islands of the Asiatic continental shelf (Sundaland) with Celebes or Lombok, or any of the islands to the eastward of these, during the entire Cenozoic. It also strongly indicates that Mindanao and the Palawan-Calamianes chain were connected by dry land with Sundaland during the Pleistocene, but that the other Philippines were never so connected during the entire Cenozoic. It further suggests that, even in the Mesozoic, there was never a dry land connection between Asia and Australia. Only three relicts of this Mesozoic fish fauna remain today—one Osteoglossid in Sundaland, another in Queensland (which has once been reported from New Guinea) and the Queensland lungfish.

The islands between Wallace's Line and the New Guinean-Australian continental shelf, and most of the Philippines (save the Palawan-Calamianes chain and Mindanao, which were part of Sundaland) are populated chiefly by fresh-water fishes of fairly recent marine origin, and which therefore give no indication of past land connections.

Most of the New Guinean-Australian fish fauna is of similar marine origin. Only the lungfish and the Osteoglossids are true fresh-water fishes, and fresh-water faunal districts in New Guinea and Australia based on fish distribution are based primarily upon fishes of close marine relationship.

There is nothing in the existing fresh-water fish faunas of New Zealand or any of the islands of Oceania east of the Philippines, New Guinea and Australia, to indicate any past continental connection.

That Japan and Formosa have only recently become separated from the mainland adjacent to each is plainly indicated by the fresh-water fishes. There is no possibility that Formosa and Luzon have been connected by continuous dry land during the greater part of the Cenozoic. Formosa has abundant native primary fresh-water fishes; Luzon has none.

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[7] Caecilians are amphibians which, unlike frogs, never appear to cross sea-barriers. Caecilians are found not only in Basilan but also on Mindanao (specimen in Stanford collection).

There is no fresh-water fish evidence to indicate a continental connection of the Galapagos with the American or other mainland.

Finally, the evidence presented here and in my 1938 paper indicates strongly that primary fresh-water fishes, of all the major groups of vertebrates, are least capable of crossing sea-barriers. The only other major vertebrate group so strictly limited by salt-water barriers are the burrowing caecilian amphibians, which are wholly tropical and very small in number. It follows that primary fresh-water fishes, above all other vertebrates, are the best indicators of the existence of sea-barriers of long standing.

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THE DISTRIBUTION OF THE FAMILY GALAXIIDAE

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The remarkable distribution of the Galaxiid fishes has been commented upon by many naturalists but none of the explanations that have been put forward is consistent with the circumstances as they now appear, and I wish to say at the beginning that I have no satisfactory explanation to offer. My purpose in bringing the subject forward is to point out the weaknesses of current hypotheses and present such evidence as I have been able to gather in the hope that some of its latent features may be brought out by discussion.

The family is represented throughout the mainland of New Zealand and in most of its outlying islands, including the Auckland Islands and Campbell Island. In Australia it extends from southern Queensland through New South Wales, Victoria and the southern part of South Australia. There is a small occurrence at the most southern part of Western Australia but no record from the west of Western Australia. Tasmania is extensively inhabited and there are records from Kangaroo Island, several small islands in Bass Strait, and Norfolk Island. A little-known species is recorded from New Caledonia, which is much farther north than the northern limit of the family's continental range. In South America, Galaxiidae occur on both sides of the Andes from about 30 s. lat. to Tierra del Fuego, which is the most southern locality recorded, and also at the Falkland Islands. In South Africa the family is represented over a considerable area in the South West Cape Region.

Interest deepens when generic distribution is considered. Three genera may be recognized: *Galaxias*, having the dorsal fin set far back in the body and 50 or more vertebrae; *Neochanna*, sharply differentiated by the absence of ventral fins; and *Paragalaxias*, which has a more anterior dorsal insertion than other genera and a low number of vertebrae—about 40. The genus *Paragalaxias* was created by Mr. E. O. G. Scott of Tasmania for a fish which he described as having biserial teeth in the jaws. All other Galaxiids had been described as having a single row. Dr. Barnard of the South African Museum, however, regarded this description as an erroneous one, and recorded the existence in South African *Galaxias* of an inner decumbent row of teeth not normally visible but which become so when the specimen is cleared in a special reagent. He expressed the opinion that a similar arrangement existed in *Paragalaxias* and that the inner row had been mistaken by Mr. Scott for an operative row. I have collaborated with Dr. Barnard in this matter and have found his surmise to be correct. Ordinary New Zealand species of *Galaxias*, *Neochanna* and *Paragalaxias* are identical in this respect with the South African form. In all Galaxiids examined there is a single operative row of teeth in the jaws and an inner decumbent row of non-rigid teeth entirely covered by tissue. Dr. Barnard regards these decumbent teeth as replacers which rise up and take the place of operative teeth that are lost, but I have not been able to observe any definite evidence that they do so, and think it desirable at this stage to recognize the possibility that they may be the obsolete remnants of an ancestral dentition.

One of the principal generic distinctions of *Paragalaxias* is therefore found to be non-existent; and the genus is now separated from *Galaxias* by the anterior dorsal fin insertion and the low number of vertebrae. The character of six rays in the ventral fins recorded in *Paragalaxias* is unsound as a generic distinction, as all forms that have been extensively investigated have been found to be variable in this feature, there being usually a dominant number with an occasional variation of one either way. In ten specimens of *Paragalaxias* examined there are two with five rays in one fin and six in the other.

Particulars of the South African species *zebratus* made available by Dr. Barnard's paper reveal the affinity of this fish with *Paragalaxias* of Tasmania. In the South African species the dorsal fin is not so far forward as in the Tasmanian one but more so than in typical *Galaxias*.

The number of vertebrae is 38-39, and the ventral fins are dominantly six rayed. These two species form a natural group which requires to be distinguished in some way, and the course that seems least likely to embarrass future revision is to retain the genus *Paragalaxias* provisionally.

A single specimen having an anterior dorsal insertion and six rayed ventrals, with the queried locality of Queensland, was described by Dr. Regan under the name of *Galaxias dissimilis*. X-ray examination of this fish shows that it has 41 vertebrae and is specifically identical with *Paragalaxias shannonensis* of Tasmania. In view of the uncertain locality of the type of *dissimilis* and the failure to re-collect the species on the mainland of Australia it seems likely that the original specimen actually came from Tasmania. The species therefore becomes *Paragalaxias dissimilis* Regan, only known locality Tasmania. The South African species becomes *Paragalaxias zebratus* Castelnau, only known locality South Africa. So far as is known the genus is restricted to Tasmania and South Africa, in the first of which localities it is associated with typical *Galaxias*, while in the second it occurs exclusively.

The distribution of the genus *Galaxias* in New Zealand covers the whole range of the family. The same position exists in Australia, Tasmania and adjacent islands, but the species from New Caledonia is of uncertain affinity, and this locality ought not to be included at present. In South America and the Falkland Islands the generic distribution coincides with the family distribution, the only species of questionable status (*Galaxias bullocki* Regan of Chile, for which Dr. Eigenmann proposed the genus *Brachygalaxias*) being geographically associated with typical *Galaxias*.

The genus *Neochanna* is restricted to New Zealand, and extends throughout the North Island, but in the South Island is known only from Westland.

Specific distribution is imperfectly known, as many species have been inadequately described, and are in need of revision. Nine species of *Galaxias* occur on the mainland of New Zealand, four of which are common to the North Island and South Island. There is one species in the North Island that does not appear to occur elsewhere, and four species are known only from the South Island. The Auckland Islands carry a species that has not been found on the mainland, and the same fish occurs at Campbell Island 180 miles away. These two localities, inhabited by a single endemic species, might almost be regarded as a distinct faunal area. *Galaxias attenuatus*, the only species known to enter the sea, and which is abundant in coastal areas throughout the mainland, has not been found at the Auckland Islands and Campbell Island. This seems the more remarkable in view of its occurrence at Tierra del Fuego and the Falkland Islands, the first of which is much farther south than the Auckland Islands, while the second are at about the same latitude and separated from their mainland by a similar distance.

There appear to be about twelve authentic species on the mainland of Australia, four of which are recorded from Tasmania where there are also three or four endemic species. *Galaxias attenuatus* occurs in New South Wales, Victoria, South Australia and Tasmania, but, so far as is known, the purely fresh-water species are all distinct from those of New Zealand.

The same position exists in South America, where there appear to be about ten endemic fresh-water species and *Galaxias attenuatus*. Several mainland species are recorded from the Falkland Islands, together with two or three that appear to be restricted to that locality.

Two species of *Neochanna* are known, one of which is restricted to the northern part of the North Island of New Zealand, while the other occurs in the remainder of the North Island and in the west of the South Island.

One species of *Paragalaxias* is recorded from a restricted area in Tasmania, and the other occurs in the South West Cape region of South Africa, where it is the only Galaxiid known.

The occurrence in such widely separated countries of closely related species of a genus that appears to be unrepresented elsewhere is particularly important from the point of view of Galaxiid distribution, the various explanations that have been put forward being all more or less affected by this circumstance. Unconvincing as current hypotheses were when only *Galaxias* was considered they become much more so with the advent of *Paragalaxias*. The popular view that fresh-water *Galaxias* have been developed from congeneric forms existing in the sea is now even less tenable than formerly. Hitherto this hypothesis involved the belief that a genus of fishes established in three oceans became extinct therein after fresh-water species had been developed in all countries between 30 degrees and 60 degrees south latitude. It would now be necessary to modify this conception by excluding South Africa and to believe that another genus (*Paragalaxias*) ranged the seas from this country to Tasmania, and disappeared in the same unaccountable manner.

A variation of the marine origin theory which has received some support in recent years is that *Galaxias* has arisen independently in all countries in which the genus is represented. It would now be necessary to admit independent evolution of *Paragalaxias* also. In large families containing many closely related genera, such as Eleotridae, it may be possible that similar combinations of generic characters would arise occasionally in different countries but this seems unlikely in a small family such as Galaxiidae. Independent evolution would be required in two genera of a family in which only three are known, and to have occurred in every country in which these two are represented. The only genus that would be excepted from this hypothetical rule (*Neochanna*) is restricted to a single country, and consequently is in no need of such an explanation.

The distribution of associated families lends no support to the hypothesis of marine origin of Galaxiidae. Retropinnidae and Haplochitonidae occur in Australia as well as in New Zealand, but the former is absent from South America and both are so from South Africa. Thus the most marine of these three families (Retropinnidae) has the narrowest distribution.

It is also to be noted that no marine group from which Galaxiidae may be conceived to have evolved is apparent, that the closest relatives of the family are fresh-water dwelling and that the only fossils known are in fresh-water beds associated with terrestrial material.

Another suggested explanation of distribution is that fresh-water *Galaxias* might be capable of performing a sea migration and so transferring themselves from one country to another. Under such conditions it might be expected that some species would occur in two or more countries but, so far as is known, the fresh-water species of each are endemic. The only species known to enter the sea, *Galaxias attenuatus*, is the only one known to occur in more than one country, but even this species is absent from South Africa and appears to be so from the Auckland Islands and Campbell Island. In most countries there are mainland species occurring in neighbouring islands, and while there seems a possibility that some of these may be capable of traversing the intervening waters it is unlikely that all are capable of doing so. Three fresh-water species are common to the North and South Islands of New Zealand, one of which is an alpine form that does not appear to be capable of even a lowland existence, much less of crossing the thirteen miles of sea that separate these islands at their nearest points.

The theory that all countries in which Galaxiidae is represented were once connected was unsatisfactory when the consideration was restricted to *Galaxias* and *Neochanna* but becomes more so with the admission of *Paragalaxias*. Under this hypothesis New Zealand, Australia, Tasmania and South America require to have been connected, and some form of independent connection is required between Tasmania and South Africa. The difficulty of reconciling the existence of these connections with the time of the inception of the family remain. The Galaxiids exhibit a degree of organization similar to that of the pikes and other Haplomous fishes which do not occur in the fossils before the Miocene. The connections outlined above would therefore require to have existed as recently as Miocene times, and unless geologists are prepared to admit that this was the case the hypothesis cannot be entertained. It may be noted here that if the hypothesis of land connection is tenable in respect of the family distribution it will explain the occurrence of identical species on contiguous islands also.

Discussion

Dr. Hubbs said that Mr. Stokell did not mention the distribution of the southern lamprey (*Geotria*) which is extremely similar to that of the Galaxiidae. Lampreys go to sea, the larvae of *Petromyzon* having been found on the Grand Banks. Experiments should be made on the larvae of *Galaxias attenuatus* to determine whether there is any possibility of sea migration. Professor Percival outlined features of the sea life of *Galaxias* and its relation with the sea. He thought that by adding sea-water gradually to an aquarium, it might be possible to determine suitability for sea migration.

THE SIZE OF ISLAND FAUNAS

By Eugene Munroe, McGill University, Montreal

[*Abstract*]

Observed figures show that the numbers of the better known animal groups inhabiting certain islands within the same archipelago bear an approximately linear relationship to the logarithms of the surface areas of the respective islands. This is true, with some exceptions, for birds and butterflies in the West Indies, and for birds in certain Malayan and Pacific island groups.

Theoretical considerations, for which the data presented provide some corroboration, suggest that the actual form of the curves is that of a shallow sigmoid, with the equation

$$F = \frac{iL}{i + kp} \, k'A$$

where F = number of species in the fauna at equilibrium, L = number of species in surrounding lands capable of immigrating into the island, i = the probability of any one of these species actually immigrating, p = the probability of extinction of a population of a single pair of one species, and A = the area of the island, to which the population number of each species is assumed to be directly proportional.

This equation applies only in cases where the tendency of autochthonous speciation to increase the fauna is negligible. Where speciation is important, as in large islands and continents, the expected size of the fauna is exceeded, but the relationship between area and size of fauna is not lost, but accentuated. This possibly offers a better basis for the dominance of Holarctica in Tertiary evolution than does Matthew's theory of the stimulating effect of cool climates.

DISTRIBUTION AND SPECIATION OF LAND BIRDS ON OFFSHORE ISLANDS, NORTHERN NEW ZEALAND

By E. G. Turbott, Auckland Institute and Museum

Several recent papers have recorded and brought up to date exploratory work upon the land birds of four islands or groups close to the northern coast of New Zealand. In this contribution an outline is given of certain problems in distribution and speciation which bear generally upon the study of insular faunas.

The distribution, on these four islands, of species of New Zealand land birds, as recorded mainly by field observation, is shown in the following table:

Resident Land Birds of Four Offshore Islands

	Little Barrier Island (7000 acres)	Taranga (Hen) Island (1175 acres)	Poor Knights Islands (480 acres)	Great I. (Three Kings Is.) (1000 acres)
Apteryx australis Shaw, kiwi	*			
Circus approximans Peale, harrier ..	x	x	x	x
Hypotaenidia philippensis (L.), banded rail	x		x	x
Porzana tabuensis (Gm.), spotless crake			x	x
Hemiphaga novaeseelandiae (Gm.), pigeon	x	x		
Nestor meridionalis (Gm.), kaka ..	x	x		
Cyanoramphus novaezelandiae (Sparrm.), red-fronted parakeet	x	x	x	x
C. *auriceps* (Kuhl), yellow-fronted parakeet	x	x		o
Ninox novaeseelandiae (Gm.), more-pork	x	x		x

	Little Barrier Island acres)	Taranga (Hen) Island acres)	Poor Knights Islands acres)	Great I. (Three Kings Is.) acres)
Halcyon sanctus V. & H., kingfisher . .	x	x	x	x
Acanthisitta chloris (Sparrm.), rifleman	x			
Anthus novaeseelandiae (Gm.), pipit	x	x	x	x
Pseudogerygone igata (Q. & G.), grey warbler	x	x		o
Petroica macrocephala toitoi (Less.), tit	x	x		
Miro australis (Sparrm.), robin . .	x			
Rhipidura fuliginosa (Sparrm.), fantail	x	x		x
Mohoua ochrocephala albicilla (Less.), whitehead	x			
Zosterops lateralis (Lath.), silvereye . .	x	x		
Prosthemadera novaeseelandiae (Gm.), tui	x	x		o
Anthornis melanura (Sparrm.), bell bird	x	x	x	x
Notiomystis cincta (Du Bus), stitchbird	x			
Creadion carunculatus (Gm.), saddleback	o	x		

Birds Naturalized in New Zealand

Chloris chloris (L.), greenfinch . .	x			
Fringilla coelebs L., chaffinch	x			x
Carduelis cabaret (P.L.S. Mull.), redpoll				x
C. carduelis (L.), goldfinch	x			x
Passer domesticus (L.), house sparrow	x			x
Emberiza citrinella L., yellowhammer	x			x
Turdus ericetorum Turt., song thrush	x	x	x	x
T. merula L., blackbird	x	x	x	x
Prunella modularis (L.), hedge sparrow	x	x		x
Alauda arvensis L., skylark	x		x	x
Sturnus vulgaris L., starling . .	x	x	x	x

* Probably from introduced stock.
o Recorded formerly.

The distributional problems may be outlined against the geographical and ecological background of the separate islands:

(1) *Little Barrier Island,* 15 miles offshore, is 7000 acres in extent. The island bears a large area of tall mixed rain-forest, providing environmental conditions similar to those on the mainland before European settlement. The land birds comprise most of those which originally inhabited the forests of northern New Zealand, and probably occur in most cases at comparable population levels. General observation on the island would place *Mohoua o. albicilla* as the most abundant species, but others, particularly *Anthornis melanura, Prosthemadera novaeseelandiae* and *Hemiphaga novaeseelandiae,* are plentiful. The naturalized birds are for the most part those restricted to a small area of garden and farm land, although some species, especially *Turdus merula* and *Fringilla coelebs,* penetrate forest as on the mainland.

(2) *Taranga (Hen) Island,* of the Hen and Chickens group, lies 10 miles from the mainland, and is 1175 acres in area. The vegetation is a dense mixed coastal forest and scrub, with regeneration forest marking the position of apparently extensive former Maori clearings.

The coastal forest is composed of fewer species than the forest of Little Barrier. The island is rich in native land birds, but in the absence of open land, only the few naturalized species which penetrate forest or scrub have become established. A census has been carried out on a portion of this island (Turbott, 1940). The most abundant species are *Prosthemadera novaeseelandiae* and *Anthornis melanura*, with *Creadion carunculatus* a less plentiful but important element.

The land bird fauna is distinguished from that of Little Barrier Island by the absence of *Acanthisitta chloris*, *Miro australis* and *Mohoua o. albicilla*. The difference in vegetation already remarked suggests no condition unfavourable to these species, particularly in the case of *Mohoua o. albicilla*. Extensive modification, possibly accompanied by fire, during Maori occupation may have had an important influence upon the land bird fauna, although the survival of some of the existing birds would then need explanation; and it is necessary to account for the failure of such an abundant and active species as *Mohoua o. albicilla* to recolonize the island.

(3) *The Poor Knights Islands*, 15 miles offshore, include two closely adjacent islands some 480 acres in total area, clothed in mixed coastal scrub with a small amount of coastal forest. The land bird fauna is extremely restricted as compared with that of the above islands. Only one species, *Anthornis melanura*, reaches a high population level. The absence of species with special habitat requirements, such as *Hemiphaga novaeseelandiae* and *Nestor meridionalis*, would seem evidently due either to the influence of the shrubby vegetation upon food and availability of nesting sites, or merely to the small area of suitable habitat; it is further possible that these species may have formerly existed only periodically or seasonally on these islands, all movements having ceased with modification of the adjacent mainland. On the other hand, there would appear to be no environmental conditions which would account for the absence of several species of adaptable requirements, especially *Pseudogerygone igata*, *Rhipidura fuliginosa* and *Zosterops lateralis*. Former Maori occupation may again have had an important effect, with the associated difficulty of explaining the absence of recolonization while the island has remained unmodified. As on Hen Island, there has been little penetration by naturalized species.

(4) *The Three Kings Islands* are separated by 35 miles from the northern point of New Zealand, lying within the strong westerlies of the Tasman Sea. This group consists of Great Island, 1000 acres in area, to be considered below in more detail, and three smaller outliers occupied by coastal forest or scrub, of from 70 to 30 acres. The history of modification on Great Island is known in some detail, so that the indirect effect of modification upon the land birds and other animal elements can be judged with more certainty than in the case of other groups (see papers by various authors in *Records of the Auckland Institute and Museum*, vol. 3, nos. 4 & 5, 1948). The original coastal forests of this island were cleared extensively by early Maori settlers, and the vegetation has since been increasingly reduced by a large population of goats. Modification ended with the complete destruction of goats in 1946: the vegetation at this stage consisted of

a uniform, open forest composed of one unpalatable plant, *Leptospermum ericoides* A. Rich (kanuka), broken only by a few mature remnants of the primary forest, and by a small area of grassland and scrub. (Baylis, 1948; Turbott, 1948.)

The apparent effect of modification upon the land birds and other animals of Great Island has been discussed by the writer in an earlier paper (Turbott, 1948). Only one land bird, *Anthornis melanura,* is now abundant; and the remainder, including a number of naturalized species which penetrate the forest, are represented by small populations. Continued modification by goats has apparently caused the extinction of four species recorded on the island within the last sixty years, and it would seem probable that in its original state the island supported a richer land bird fauna.

The regeneration of the vegetation on Great Island is now being recorded, and it is believed that there is sufficient descriptive material to indicate the course of succession in certain animal groups, including the land birds. In particular, the possibility of modification in habits as well as in population densities, and of recolonization from the mainland or from more distant stations are likely to be significant with regard to distribution.

It must be evident that further investigation both on the islands and the mainland may explain these distributional problems in terms of competition or of other ecological factors. Alternatively, failure to colonize apparently suitable environments suggests the possibility of assessing dispersal faculties. Studies of insular land birds, particularly those by Mayr in the Austro-Malayan archipelago and adjacent Pacific, show that even apparently sedentary species (e.g., the *Rhipidura rufifrons* group: Mayr and Moynihan, 1946) may achieve widespread dispersal over long periods of time. In the area under consideration it would seem probable that in certain species, which may have succumbed comparatively recently to modification of the habitat and other extinction factors, recolonization has not yet occurred simply because of limited dispersal faculties. In some cases modification of the mainland as the result of European settlement might restrict movements which would formerly have resulted in more immediate recolonization.

As for direct evidence of dispersal, the record of colonization by apparently sedentary small passerine birds naturalized to the mainland is one of the most notable aspects of the above lists, although less remarkable when it is considered that elsewhere in the New Zealand region naturalized birds such as *Carduelis cabaret* and *Turdus merula* have reached such distant outlying islands as Macquarie Island and the Chathams. Observations of passage by indigenous species in the present area have been made in a few instances, including that of *Anthus novaeseelandiae* observed between Little Barrier and the mainland.

Consideration may also be given to the possible effect of genetic homogeneity, in bringing about extinction on small islands which would support only low populations. This effect would require the isolation of small populations over considerable periods, conditions characteristically found on the most geographically isolated oceanic islands. It seems possible that extinction in relatively sedentary species may also follow colonization movements taking place at long intervals.

on islands less distantly situated from other stations. A possible instance of extinction from this cause is that of *Pseudogerygone igata* on South West Island, one of the unmodified small members of the Three Kings group. It was recorded from this island, of total area only 70 acres, in 1889; and in the same year from Great Island, where it had already been subjected to reduction over some hundreds of years. There may originally have been regular interchange with Great Island, only three miles distant; but with the modification of the larger island all such movements would have ceased.

Finally the evidence of evolutionary change provided by the small collections available may be briefly discussed. Material of several species has been found to conform to that from the mainland, but is insufficient to indicate the absence of geographic variation.

Falla (1948) has shown that *Anthornis melanura* falls within mainland series on Little Barrier Island, and the Hen and Chickens and Poor Knights groups, but is represented by a well-established subspecies, *Anthornis m. obscura* Falla, on the Three Kings Islands. The Three Kings subspecies is characterized by its longer bill, and darker plumage with the replacement of yellow colouring by white. Subspeciation would indicate that this species is relatively sedentary in relation to an ocean barrier of moderate extent, but lying athwart the prevailing wind.

An evolutionary divergence which is possibly more recent is recorded by Turbott and Buddle (1948) in *Rhipidura fuliginosa* on Great Island, the modified main island of the Three Kings group. The numbers of this species were probably reduced as the result of clearing during some centuries of Maori occupation, followed by intensive reduction of the vegetation by goats for at least sixty years. At present the total population is estimated at not more than fifty. Of the small amount of material available, some specimens are distinguishable from *Rhipidura fuliginosa* of the mainland by a distinct band of white-tipped feathers on the upper breast and by the paler colour of the under surface; but a specimen is included in this collection which cannot be separated from mainland series. In a population of this size it seems possible that the establishment of non-adaptive characters could be explained on the basis of the Sewall Wright effect. Should the population have remained small owing to continued impoverishment of the habitat, the normal phase might have been replaced by the mutant, resulting in the establishment of a subspecies.

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DISCUSSION

In reply to a question by Dr. Godley, Mr. Turbott said that as far as is known the mutant of *R. fuliginosa* occurs only on Great Island. Dr. Falla suggested that these results from the outlying islands should be followed up by more work on the mainland birds, the material available from the mainland being insufficient to show the presence or absence of a mutant. Dr. Austin explained something of genetical studies on speciation in birds being carried out by Japanese workers.

ON THE EVOLUTIONARY AND DISTRIBUTIONAL HISTORY OF *MALACOPTERON* (AVES, TIMALIIDAE)

By K. H. VOOUS, Zoological Museum, Amsterdam.

[*Abstract*]

1. The babbler genus *Malacopteron* is restricted to Malaysia. It consists of six exceedingly similar species, five of which may be together in the same habitat in the Malay Peninsula, Sumatra, and Borneo. The isolating mechanisms between these species, as well as the ecological differences that permit them to coexist, are not yet known.

2. The origin of these six species is correlated with the Pleistocene shifts of sea level. Some of the subspecies have evolved since the end of the Pleistocene.

3. Of the characters that vary in this genus, some seem to have adaptive significance, like the colour of the head and general size; others seem to be neutral, like the presence or absence of a breast band and stripes on the throat.

GENERAL CONCLUSIONS

(1) The genus *Malacopteron* is very closely related to *Malacocincla.* It consists of six species of babblers (Timaliidae) which lead an arboreal life, preferably in low bushes, and have in general the habits of bulbuls (Pycnonotidae). In adaptation to this arboreal mode of life the tarsus of *Malacopteron* is shorter and the tail longer than in the terrestrial genus *Malacocincla.*

(2) *Malacopteron* has a typical Malaysian range.

(3) *Malacopteron* has six sibling species. They are exclusive lowland birds, and as many as five occur alongside each other in the same habitat in several localities of the Malay Peninsula, Sumatra, and Borneo. However, still unknown slight ecological or ethological differences may exist between these species.

(4) Speciation in *Malacopteron* seems to have taken place during periods of geographical isolation. There is no evidence for ecological or any other form of sympatric species formation.

(5) Geographical speciation in *Malacopteron* has taken place from the end of the Tertiary until now. During phases of high sea-level several isolated insular populations have reached the stage of a distinct subspecies. During the next following phase of low sea-level the island forms extended their ranges over the emerged Sunda lowlands and came into contact with the other island forms. Eventually some of these subspecies proved to be not only taxonomically differentiated

but also reproductively isolated from their original geographical representatives and spread over the whole Sundaland without interbreeding. Thus, this originally insular subspecies had reached the stage of a species. While spreading over the Sundaland it could reach the other islands so that the beginning of the next following period of high sea-level found it an inhabitant of all again separated Sunda Islands. Once more subspecific differentiation by insular separation could start in this new species.

(6) Post-Pleistocene subspecies formation has occurred in *magnirostre* (increase of size) on the Anamba Islands, and in *cinereum* (decrease of size) on the North Natuna Islands.

(7) No appreciable distinguishable racial differentiation has taken place during the post-Pleistocene in the *Malacopteron* populations inhabiting the west Sumatran Islands.

(8) A case of parallel mutation has been discussed: a black cap must have been present in *affine* before the last insular separation. Independently, a black cap developed in *magnirostre* during the post-Pleistocene in the Bornean populations which, however, are still slightly variable in this character.

(9) Taxonomic characters, which probably have a selective value in the speciation of *Malacopteron,* are the coloration of the head and general size. These characters may belong to those species characters mentioned by Mayr that are said to help to maintain the isolating gap between species, whereas the other characters, e.g., the presence or absence of a breast band and throat stripes, seem neutral in this respect.

(10) The difference between the sexes is very small in *Malacopteron* and consists only of the somewhat larger size of the males. No sexual difference exists in coloration.

(11) The sex ratio is very low in the genus. It is especially low in *magnum,* in which species only 21 females per 100 males are present in collections. Evidence exists that this proportion approximately represents the real situation in nature. This fact, as well as the close taxonomic resemblance of *magnum* and *cinereum,* may have acted as stimulating factors in producing three interspecific hybrids, which have been discussed in detail.

(12) The fact that in Borneo *affine* is by far the predominating species of *Malacopteron*, whereas *cinereum* is the predominating one in Sumatra, may be considered to be indicative of strong interspecific competition. With the exception of *albogulare*, *affine* is the least common species of *Malacopteron* in Sumatra, whereas *cinereum,* in turn, belongs to the less common species in Borneo.

(13) The rather high rate of interspecific competition in *Malacopteron* is probably the result of (a) the adaptation of all species to much the same biotope and (b) the close morphological resemblance of at least four species of the genus.

(14) On account of its rarity, its highly interrupted range, and its isolated taxonomic position, *albogulare* is regarded as the oldest member of the genus, having long followed its own lines of development.

(15) The Palawan form (*palawanense*) is much younger, but must be the next oldest for the following reasons: (a) its range is situated at the limits of the Sunda lowlands, (b) it is the only representative

of the genus on Balabac and Palawan, (c) though it is an arboreal bird, it shows a slight approach towards *Malacocincla* in having a rather long tarsus, (d) the coloration of the crown is plain brown and uniform with the remaining upperparts. Besides, *palawanense* shows a convergent development with *magnum* in having large dimensions and a robust bill.

(16) The brown-headed forms of *cinereum* from Indo-China and Java seem to be the next following in age of development. It is likely that these widely separated forms once inhabited a continuous range.

(17) The further sequence of taxonomic development and distributional history of *Malacopteron* cannot be traced, but it seems reasonable to suggest that a uniform brown crown came before the stage of a brown head with a black occiput. In favour of this supposition the Northeast Bornean race of *magnum*, which inhabits a range shared with other avian relicts, has a much less developed black occiput than the other races of *magnum*, being intermediate between the disjunct brown-headed forms of *cinereum* and those forms of *cinereum* and *magnum* which have a broad black occiput.

(18) In consequence of the fact that the Malay Peninsula, Sumatra, and Borneo each are inhabited by five species of *Malacopteron*, whereas Java possesses only one, the island of Java must be considered to have been less accessible to exclusive lowland birds, probably because of its mountainous character and the fact that it has probably not been connected to the main Sundaland at each stage of low sea-level.

(19) Apart from the other generally accepted geographical barriers, the north Malayan and the Philippine mountains, as well as narrow sea channels which have remained between Palawan and the Philippines during the Pleistocene phases of low sea-level, have acted as distributional barriers to the exclusive lowland bird species of the Sundaland like *Malacopteron*.

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THE MORPHOLOGICAL, ANATOMICAL, AND DISTRIBUTIONAL RELATIONSHIP OF THE ARCTIC AND ANTARCTIC FULMARS (AVES, PROCELLARIIDAE)

By K. H. Voous, Zoological Museum, Amsterdam

[*Abstract*]

THE similarity of the Arctic fulmar, *Fulmarus glacialis* (L.) ,and the Antarctic fulmar or silver-grey petrel, *Priocella glacialoides* (Smith), has aroused attention but this is the first comparative study of the two species.

These species are alike in plumage and size, the principal difference being in the shape of the bill. The northern fulmar has transverse lamellae on the upper mandible but this is not a generic criterion. There is a distinct dark colour phase of the northern fulmar which has never been established in the southern species.

The two fulmars appear to be more similar to one another than other members of the family in the average length of the bones of arm and leg. In the formation of the tracheal septum and the syrinx they are intimately related.

The breeding ranges are situated on the opposite sides of the globe. The southern fulmar is a circumpolar Antarctic birds and the northern typically Arctic. The favoured nesting sites of both species are steep cliffs on large and small islands, the colonies containing thousands of birds.

The northern fulmar is the most numerous bird of the Arctic pack ice, whereas the southern species is slightly less abundant in the Antarctic. In contrast to the stationary habits of the Arctic species the Antarctic fulmar shows distinct seasonal movements, mainly following cool sea currents.

There is evidence that the Arctic fulmar is a Pleistocene or earlier descendant of the Antarctic one. It seems likely that in the Pleistocene, the Arctic regions which remained accessible to sea birds shifted southwards and the extension of the Antarctic glaciers moved the breeding localities of Antarctic birds northward. Under these conditions the southern fulmar must have succeeded in colonizing the North Pacific and subsequently spread through the Arctic Ocean to the North Atlantic.

The food of the two fulmars consists of planktonic Crustacea and Cephalopoda, and oily matter. The presence of food competitors in the Antarctic oceans, which are the home of many species of petrels, and the absence of these in the north, may have led to the enormous development of the fulmar populations in the Arctic seas, which is unequalled by those in the south.

In conclusion it appears that no fundamental reasons exist in favour of the generic separation of the Antarctic and Arctic fulmars. Indeed, these species may be united into one super-species. The Arctic fulmar seems to be a Pleistocene or earlier descendant of the Antarctic one, which must have reached the Northern Hemisphere along the cool waters of the west coast of America. The Antarctic fulmar is still the more generalized form, its Arctic descendant the more developed. The closest relative is *Thalassoica antarctia* (Gm.), the Antarctic petrel, which structurally and ecologically is extremely close to the fulmars, from which it mainly differs in its colour pattern. However, *Thalassoica* is less specialized than the fulmars, "both as regards its imperfect tracheal septum, and the number of rectrices", a fact which has been noticed already by Forbes (1882).

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PHENOTYPICAL DIFFERENTIATION OF ENDEMIC BIRDS IN RELATION TO ISLAND SIZE IN MICRONESIA

By Yoshimaro Yamashina, Yamashina Ornithological Institute, Tokyo

Students of evolution are well aware of the important role of islands in the development of living organisms. However, so far as birds are concerned, most investigators have dealt chiefly with the relation between richness of the avifauna and the ecological conditions of the island supporting it. Rarely have they been concerned with the relation between the amount of phenotypical differentiation on each island and the environmental conditions, past or present, of the island on which it developed. Lack, in his studies on the Darwin's Finches of the Galapagos Islands (1947) states his belief that the effects of isolation and adaptation are the most important factors influencing speciation of birds in those islands, and admits the effects of accidental elimination and recombination of hereditary characters suggested by Wright (1940) only in a few cases of subspeciation. My recent studies on Micronesian birds suggest the existence and effectiveness of such non-adaptive differentiation factors not only in the development of subspecies, but also in the formation of species and genera. The evidence leading to this conclusion follows.

The following Micronesian islands contain endemic land birds:

North Mariana Islands: Assongson, Agrigan, Pagan, and Almagan.
South Mariana Islands: Saipan, Tinian, Agiguan, Rota, and Guam.
Caroline Islands: Yap, Wolea, Lamotrek, Truk, Lukunor, Nukuoro, Ponape, and Kusaie.
Palau Islands: Babelthuap, Koror, Peliliu, Angaur, Pulo Anna, etc.
Marshall Islands: Jaluit, Iringlob, Arhno, Wotze, and Bikini.

About 38 endemic species and 5 endemic genera live in these islands (cf. Handlist of Japanese Birds, 3rd ed., 1942; Mayr 1945).

These islands may be classified into five types, based on their origin and probable age as follows:[1]

I. Coral islands.
II. Islands formed by extrusion of andesite in the Pleistocene and Holocene.
III. Islands of Pleistocene emergence.
IV. Islands of probable Pliocene emergence.
V. Islands formed by extrusion in the early Tertiary.

I. *Coral Islands*:

Coral islands, formed only of coral reefs, are found in the western Caroline and the Marshall groups. The wide spread species, *Acrocephalus luscinia* is met with in Wolea, Lamotrek, Lukunor, and Nukuoro in the Carolines, and *Ducula oceanica* occurs in the Marshalls. Except for *Ducula oceanica ratakensis* in the Ratak chain, they do not vary even subspecifically, indicating quite recent tenure of their present habitats.

II. *Islands Formed by Extrusion of Andesite in the Pleistocene and Holocene*:

The North Mariana Islands were formed by extrusions of andesite from the Pleistocene onward. Some of these islands are still active volcanoes. The following six land-birds have been collected in these volcanic islands:

Myzomela rubratra: Assongson, Agrigan, Pagan, and Almagan.
Acrocephalus luscinia: Pagan.
Halcyon chloris: Assongson, Pagan, Almagan.
Gallicolumba xanthonura: Assongson, Pagan, and Almagan.
Gallinula chloropus: Pagan.
Megapodius laperouse: Assongson, Agrigan, Pagan, and Almagan.

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[1] I am highly indebted to Professor Risaburo Tayama of Tohoku University for supplying the accompanying geological data on the Micronesian Islands.

All these species are widely distributed throughout the Marianas, or the whole of Micronesia, and only two species, *Acrocephalus luscina* (*yamashinai*) and *Halcyon chloris* (*owstoni*) differ subspecifically from those of the South Marianas. Therefore, these land-birds must have appeared fairly recently in these newly-formed volcanic islands.

III. *Islands of Pleistocene Emergence.*

Rota and Tinian in the South Marianas are said to have originated by submarine volcanic action during the Miocene, and to have emerged above the sea surface in the Pleistocene after coral-limestone deposition during the Pliocene. Rota emerged later than Tinian. Tinian has 13 land birds and Rota 11. All except one species in Tinian, *Monarcha takatsukasae,* are distributed throughout the whole Marianas. This fact indicates that the island is too new to have formed a number of new species or races.

The one unique endemic bird in Tinian island deserves further comment. *Monarcha takatsukasae* is a most interesting species from the evolutionary point of view. It is one of the slender-billed Broadbills, showing characteristics of *Monarcha,* but if the adult plumages alone are compared, without near relatives in the neighbouring islands. However, the plumage colour and body structure of this bird show remarkable similarities to the juvenile of the Yap Broadbill, *Monarcha godeffroyii.* The only differences between them are slightly larger size and duller colour of plumage in the latter. This fact combined with the geological history of the island indicates that *Monarcha godeffroyii* must be the ancestor of *Monarcha takatsukasae. M. godeffroyii* probably came to Tinian when the island was still very small, immediately after its emergences above the sea surface. The ancestor of the *Monarcha tagatsukasae* must have had a very small population at some geological period, and atavistic mutation and dimidiation probably produced the new species despite the youth of the island.

IV. *Islands of Probable Pliocene Emergence.*

Truk, Kusai, and Guam are said to be similar in age. The basic strata of these islands are said to be pre-Miocene rock, basalt in the two former, andesite in the last. These islands appeared above the sea-surface in the Pliocene, and are rather old compared with the islands mentioned previously. Each island has a number of endemic birds as follows:

Truk Island:
Kubaryum ruki[2]
Myiagra oceanica
Metabolus rugensis (Muscicapidae)

Kusai Island:
Aplonia corvina
Aphanolimnas monasa (Rallidae)

Guam Island:
Myiagra freycineti
Rallus owstoni

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[2] Mayr (1944) selected *Rukia* Momiyama, Birds of Micronesia, p. 2 (1922) for this genus, but *Kubaryum* Momiyama, *l.c.*, p. 1 (1922) has page priority over *Rukia,* and must be used instead.

Such species as *Corvus kubarvi* and *Ptilinopus roseicapillus,* which are not endemic to Guam, but to the whole South Marianas, might have been formed in Guam.

Here we must notice that single monotypic genera exist respectively on Truk (*Metabolus*) and Kusaie (*Aphanolimnas*), but none on Guam. This phenomenon may be explained as follows. These three islands are similar in age as mentioned above, but the shape of the mountain forming the islands is different. Truk and Kusai are formed by single cone-type volcanoes having very slender summits and steep slopes. Thus the area of the islands must have been very small, especially in their period of submergence, though the peak of the island, at least, is believed to have been always above the sea. The ancestor of *Metabolus*, which might have been of *Monarcha* stock, and that of *Aphanolimnas*, which was perhaps related to *Porzana tabuensis,* probably came from somewhere in the Melanesian Islands and survived in these very small islands in very small populations. Under such circumstances a peculiar type could easily have developed. On the other hand, Guam was not originally a single cone-type volcano, and its area therefore was never as small as Truk and Kusai once were, even at its period of extreme submergence. Race-formation by the spreading of mutant genes was discouraged in Guam by the larger population it supported. Therefore no monotypic genus, characterized by extreme morphological differentiation, was formed on Guam despite its similarity in age and origin to Truk and Kusai.

V. *Islands Formed by Extrusion in the Early Tertiary.*

Saipan, Yap, Palau, and Ponape are said to be islands of this type. They are the oldest and largest of the Micronesian islands. The endemic species of birds found in these islands are as follows.

Saipan: *Cleptornis marchei.*

Yap: *Kubaryum oleaginea, Edolisoma nesiotis, Monarcha godeffroyii.*

Palau: *Kubaryum palauensis, Zosterops finschi, Colluricincla tenebrosus, Lalage monach, Psamathia annae, Otus podargina, Gallicolumba canifrons.*

Ponape: *Aplonis pelzelni, Kubaryum longirostra,*[3] *Lalage insperata, Trichoglossus rubiginosus.*

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[3] Mayr (1933, 1944, 1945) insists on the validity of the name *Rhamphozosterops sanfordi* Mayr for this bird, basing his claim erroneously on priority of publication. *Cinnyrorhyncha* (*Kubaryum*) *longirostra* TakaTsukasa and Yamashina was described in vol. 43, no. 516 of *Dobutsugaku Zasshi* dated 15 Oct. 1931, and mailed 19 Oct. 1931, at least 16 days before the description of *R. sanfordi* Mayr was published. Mayr (1944, 8) refutes this date, claiming the description of *C. longirostra* was not published until 23 Nov. 1931, a fact he ascertained "by correspondence with leading American and European ornithologists and libraries". The date he mentions, 23 Nov. 1931, is the publication date of vol. 43, no. 517 of *Dob. Zasshi.*

All members of the Zoological Society of Japan residing in Tokyo received no. 516, containing the mooted description, between 20 and 25 October, as verified by the library records of the Yamashina and Kuroda libraries (unfortunately destroyed during the war) and by the Momiyama diary, fortunately still extant, which shows this particular number reached his residence in Sasazuka, near Tokyo, 24 Oct. 31. Therefore, according to the International Code of Nomenclature, *C. longirostra* TakaTsukasa and Yamashina has priority over *R. sanfordi* Mayr, and must be accepted as valid.

I consider *Cinnyrorhyncha, Megazosterops,* and *Kubaryum* to be congeneric.

Among these endemic birds we find only two monotypic genera, *Cleptornis marchei* (Meliphagidae) and *Psamathia annae* (Sylviidae) in Saipan and Palau respectively. This apparent anomaly may be explained by the geological history of each island. Ponape and Yap are believed always to have been large in area. Ponape was originally a dome-type volcano, with a very wide flat summit. Therefore, the land area of the island was apparently large, even when the island was in extreme submergence. The geological origin of Yap is peculiarly unique. The basic stratum of this island is amphibolite, which is usually found on continents, not in oceanic islands. Some investigators therefore consider this island to be a remnant of a lost continent. The hypothesis is very doubtful, but it is generally accepted that the size of the island has been larger in the geological past than today. Thus the population of immigrant birds in these two islands probably were not small enough over a long enough period to allow for strong differentiation to develop. Therefore, Ponape and Yap have no monotypic genera, though they have several endemic species. On the other hand, Saipan was a cone-type volcano with a very narrow summit similar to those of the North Marianas. In the time of its extreme submergence, only a very narrow peak, now called Mt. Sankaku, appeared above the sea-surface. The entire island, except Mt. Sankaku, is covered with tertiary coral-limestone. In Palau Island where the highest peak is only 240 metres above the sea, the Tertiary coral-limestone covers about 200 metres above the sea surface. Thus only 40 metres of summit was above the sea surface when Palau was in extreme submergence. Conditions in Saipan and Palau were, therefore, quite similar to those in Truk and Kusai, and the small ancestral populations of *Cleptornis* and *Psamathia* could similarly have differentiated strongly in these small solitary, well isolated islands.

Discussion and Conclusions

All the Micronesian islands are of volcanic origin, extruded independently from an underwater ridge on the bottom of the South-west Pacific Ocean. There is no evidence of any land-bridge having existed either between each island or between the islands and neighbouring lands. That is to say, all Micronesian Islands are purely oceanic.

We must consider therefore that all land-birds living in these islands have immigrated of their own accord from neighbouring land areas, excepting those few species which were imported by man.

Some species of birds, generally regarded as resident and non-migratory, sometimes appear to make sudden long journeys. In the Bonin Islands *Corvus coronoides japonensis* was once a resident, but was extirpated before 1920. A flock of about 17-18 *Corvus corone orientalis* suddenly appeared in the islands in November, 1933 (Yamashina 1934), and was totally destroyed by hunters within a year. This shows, however, that birds which are usually sedentary, may migrate to remote oceanic islands.

Phenotypical differentiation after birds have immigrated to an island is affected by the degree of isolation, the frequency of gene mutation, the number of generations, the size of population, and the degree of selection. Here in the oceanic islands, the isolation is practically complete. The frequency of gene mutation has no apparent relation to size of islands or populations. They have been sufficient to produce varying degrees of phenotypical differentiation in the birds living on every island in question. Therefore, the other three factors, number of generations, size of population, and degree of selection must be the major determinants.

All the islands supporting monotypic endemic genera were once very small in area. Namely, Palau and Saipan among the older islands and Truk and Kusai among the newer, possess endemic monotypic genera equally, while older Yap and Ponape, which have always been larger have only endemic species. Among the comparatively newer islands, only Tinian, which once was very small, has an endemic species. These facts suggest that the smallness of the size of population must be an important factor in the phenotypical differentiation of birds in oceanic islands.

Hardy (1908) and Wright (1921, 1940) have proved statistically that race formation is advanced without selection in a certain direction, if the frequency of gene mutation is sufficient. These observations in the Micronesian islands, while endorsing Hardy's and Wright's theory to some extent, suggest that smallness of populations is more important than length of tenure and natural selection in the evolution of animals in isolated oceanic islands.

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DISCUSSION

The paper was read by Dr. Oliver L. Austin.

In discussion, Dr. Falla said that similar cases of birds from distant countries having reached New Zealand might have resulted from abnormal hurricane conditions. Dr. Murphy considered that the paper was highly speculative. He mentioned small differences in size of the bill in birds on small islands as compared with their representatives on the nearest mainland, and gave an example from the Bermudas. Mr. Fleming referred to the possible effect of small numbers upon speciation of land birds on the outlying islands of New Zealand, stating that he had found some evidence in forms under consideration in support of the Sewall Wright theory.

THE AFFINITIES OF *PITYRIASIS* OF BORNEO

By Masauji Hachisuka, Yamashina Ornithological Institute, Tokyo

Pityriasis is a peculiar monotypic genus of birds confined to the forest of Borneo. The head of the adult *Pityriasis gymnocephala* is entirely devoid of feathers and has small hair-like spicules in their place. In spite of its rareness, specimens have been collected by most of the naturalists who have visited Sarawak. Considerable field observations have been made, but its systematic affinities are still unsettled. The native name of this bird is "Tiong Bali" which means "Phantom Myna". Its size, black plumage with wing bar, and short tail, coupled with whistling notes, suggest that it is one of the mynas. Yet, it is considered an aberrant shrike by many authorities.

R. Shelford (*Ibis*, p. 167, 1899) hoped to undertake the anatomical study of *Pityriasis* to determine its family relationships, but apparently published nothing. Even among modern authorities opinions vary: it was placed under the Laniidae by Chasen ("A Handlist of Malaysian Birds", 1935) and was included tentatively in the Sturnidae by Delacour ("Birds of Malaysia", 1947) and by Amadon (The Genera of Starlings and their Relationships, *Amer. Mus. Novitates,* 1247, 1943).

MORPHOLOGY

The Sturnidae, the starlings and mynas, constitute a fairly well defined family and their general structure does not vary much. A large, black-coloured group superficially resembling *Pityriasis* includes *Gracula,* the Hill Myna, of the Oriental region, and *Mino,* the Papuan Myna, of New Guinea. *Gracula* is characterized by its well developed yellow naked lobe-like wattle on the hind head; *Mino* has a large yellow naked area on the face, the skin formation of which is quite similar to that of *Pityriasis.*

Nakedness about the head is not a usual character among Passeres. The males of the Paradise Flycatcher, *Terpsiphone,* of the Oriental region, and *Neodrepanis,* the Wattled Sunbird of Madagascar, have wattles around their eyes; *Heteralocha,* the Huia of New Zealand, and several large species of Meliphagidae, the honeysuckers, of Melanesia also possess this characteristic. The strange *Allotocops calvus,* a timaline bird also from Borneo, has a naked head in both sexes although its Sumatran subspecies is completely feathered. More naked than *Mino* among Sturnidae is *Sarcope culvus* of the Philippines, but the skin of its head is smooth, its plumage is black and grey, and its shape is genuine sturnine, more slender with a longer tail. The nakedness of the head is therefore a secondary superficial characteristic appearing locally among restricted groups of birds, and of no great importance systematically.

Plumage strongly tinged with metallic green and purple is fairly universal among starlings (the African glossy starlings are notable examples), but metallic sheen is exceedingly rare among the shrikes. On the other hand sooty black is well known among the latter and even appears as a dimorphism in the Oriental region: (*Lanius schach* form. *fuscatus*). The plumage of *Pityriasis* is sooty black.

The colour of the bill in the mynas is always yellow or orange, but it is always black or dark brown in the shrike family. *Pityriasis* has a black bill. The mynas have rounded nostrils but in *Pityriasis* they are horizontal slits. Shrikes' nostrils are not constant in shape, so the presence of this character in *Pityriasis* does not carry much weight.

The most important points are the shape and proportion of the head and legs of *Pityriasis*. In the shrikes, the head is very large and broad, the bill is equipped with a notch on the cutting edge of the upper mandible, and the legs are small and chiefly fit for perching. The mynas have normally shaped heads and powerful legs which enable them to walk on the ground with ease. *Pityriasis* has an even more massive head than the average shrike, and a powerful notched bill. Its legs, although strong, are comparatively small. It is not known to what extent *Pityriasis* hunts on the ground, but the relative proportions,, or rather disproportions, of the head and legs undoubtedly must affect the bird's habit to a great extent.

Shrikes, unlike the Sturnidae, are not constant in structure and pattern. They are divided into several natural groups, some genera being green, yellow, or red, and their habits are not unlike those of the Flycatchers, having small heads and normally lengthened tails; but all are characterized by bills with hooks and notches to a greater or lesser degree. On the other hand no shrike is devoid of feathers in any part of the body. The typical genus of shrike, *Lanius*, may be considered as the taxonomic centre of this heterogeneous group.

In "The Catalogue of Birds", viii, p. 90, 1883, Gadow classified *Pityriasis* as belonging to the subfamily Gymnorhininae, in the Laniidae, which also embraces *Gymnorhina* and *Cracticus*. According to the "Official Checklist of Australian Birds", 1926, this grouping is parallel to Streperidae (this should be called Cracticidae, because *Cracticus*, 1816, antidates *Strepera*, 1930) adding *Strepera* to the two other Australian genera just mentioned. Among those three genera, *Cracticus* is probably nearest to *Pityriasis* because it has a fairly large head and a similarly shaped bill.

FIELD OBSERVATION

According to Everett (Sharpe, *Ibis*, p. 20, 1877) *Pityriasis* is one of the rarest birds in Sarawak, and he writes as follows: "My hunters were so fortunate as to come across a large flock on the hills near Marup, out of which they secured a dozen specimens (April, 1871). After each discharge of a gun the flock returned to the same spot until the wounded bird cried out, when they all flew off. An examination of the contents of the gizzards in several individuals, showed that their food consists of arboreal Orthoptera, cockroaches, beetles, and some large green larvae." Hose (*Ibis*, p. 394, 1893) indicates the same habit of flying down to their wounded comrade, and adds the following about their diet: "This bird is particularly fond of a berry which is bluish black in colour, about the size of a pea. It shells the fruit off the stone with its bill and devours the pulp." Hose ("The Field-Book of a Jungle-Wallah", p. 155, 1929) wrote later about "an unpleasant and brutal habit which it is said to have of turning upon its own friends and attacking them when wounded".

The voice of *Pityriasis* is described as very harsh but at times it utters a whistle not unlike that of a myna. It builds a nest in a natural hollow of a tree, and the only known egg, preserved in the Kuchin Museum, Sarawak, is described by G. Bartlett (*Ibis*, p. 158, 1896; *ibid.*, p. 167, 1899) as: "about the size of the Thrush's . . . it is pure white, sparingly marked all over with large round and oval bright brown and slate-grey spots of various sizes, the majority of those spots forming an irregular ring on the large end".

We note that some of the field observations given above, such as the diet and song, may be referrable generally both to the mynas and the shrikes, but if the cannibalism is authentic it suggests an important link between *Pityriasis* and the shrikes. Starlings nearly always lay pale uniform green or blue eggs, seldom spotted, while shrikes lay spotted ones. Starlings always nest in a hole, whereas shrikes build their own nest among branches; but nesting habits do not always constitute a consistent family characteristic. The Jackdaw and the Lidth Jay of Okinawa, unlike other crows and jays, nest in holes; the same is true of the Sheldrake, Mandarin and Golden-eye among the ducks. Little auks and puffins nest in holes burrowed in the ground, while the majority of their allies build open nests or deposit eggs directly on cliff edges. Parrots are well-known hole breeders, but *Myopsittacus monachus* of Argentina builds a very elaborate domed nest of twigs.

Cracticus and *Gymnorhina* of Australia feed on caterpillars and locusts, and lay eggs which are thickly spotted particularly at the large ends. Bartlett (*Ibis*, p. 159, 1896), judging from the eggs of *Pityriasis*, thought its nearest ally would be *Gymnorhina*, as already suggested by Gadow.

Conclusion

The facts given above are not by any means adequate to determine the true affinities of *Pityriasis*, as nothing is known of its internal anatomy, but I am satisfied that its supposed affinity to the mynas may be dismissed, and although strikingly aberrant, its relationship may be traced to Cracticidae, of which *Cracticus* is the nearest. This family is quite close to the Laniidae and if one wishes to lump the classification, it may be considered as a branch of the Laniidae. Therefore, *Pityriasis* is most likely an aberrant member of the shrikes.

From the distributional point of view, the Australian element is practically nonexistent in Malaysia. *Megapodius*, *Trichoglossus* and *Cacatua* exist on small islands in this region, but they belong to the same species found in the southern islands and may be considered recent invaders. Therefore, the existence in Borneo of an Australian element represented by a different genus, which may be looked upon as a very early arrival, is singularly interesting. This zoogeographical viewpoint accentuates the peculiarity of *Pityriasis*.

PARASITES AND EVOLUTION

By T. W. M. Cameron, McGill University, Montreal

[*Abstract*]

A parasite is an organism which has lost part of its holozoic (or holophytic) heritage and has become to some extent at least, dependent on its host for some of its foodstuffs. This loss is probably

associated with the degradation of certain enzyme systems and has to be made good by the substitution of equivalent systems by the host. This gives rise to host-specificity and some parasites are much more host-specific than others.

In general, it is a function of evolutionary age and specialization and the more divergent a parasite is from the main phylogenetic strain, the more it tends to be host-specific. Because parasites become specialized and often simplified, taxonomy must include all the biological as well as the morphological characters of the organism and it can be used not only to help trace the evolution and relationship of the parasites but that of their hosts as well, and examples are presented from the Sporoza, the Cestoda, the Nematoda, and the Insecta.

THE DISTRIBUTION OF TAPEWORMS IN THE PACIFIC AREA AND THE CONCLUSIONS TO BE DRAWN THEREFROM

By Robert A. Wardle, University of Manitoba, Winnipeg

Between those islands of the Pacific Ocean that lie approximately east of Wallace's Line, as represented by the Borneo-Celebes and Bali-Lombok straits, and south of the equator—but excluding the Galapagos and Juan Fernandez groups—, and those islands that lie approximately west of Wallace's Line and north of the equator, there are, as is well known, very marked faunal differences which stem from the geological schism of the southern Pacific islands from an Afro-Asiatic land mass early in the Cretaceous Period, or, if the absence from Australia of edentates, insectivores and didelphid marsupials, can be explained otherwise, as late as the beginning of the Tertiary Period.

As regards vertebrates, with which, as potential hosts of tapeworms, we are concerned here, the outstanding features of this southern region are, broadly speaking: (1) the almost complete absence of Ostariophysi, that large order which comprises the great majority of true fresh-water fishes; (2) the absence of Amphibia other than Anura and the predominance among these of the arciferous forms; (3) the relative poverty of the region in reptiles, other than geckos, skinks, agamids, iguanids, varanids and non-viperid snakes; (4) the predominance of ratite birds and of the carinate families, Megapodiidae, Paradiseidae, Menuridae, Meliphagidae, Psittacidae and Columdidae; and (5) the absence of placental mammals and the restriction to the region of all marsupials except didelphids and epanorthids.

Further details are available in zoogeographical treatises and need not be repeated here.

In trying to correlate these facts of vertebrate distribution with the distribution of tapeworms the student is handicapped somewhat by the scarcity of helmithological information for the region. Yet there is sufficient information as will be evident from the list of references appended, to justify certain conclusions. That these conclusions apply mainly to Proteocephala, to difossate tapeworms (Spathebothridea, Caryophyllidea, Pseudophyllidea) and to Stem-Cyclophyllidea does not detract from their interest to the student of tapeworm phylogeny, as these groups have each had their advocates for the claim of being nearest to the original tapeworm stock.

The differences in tapeworm distribution between the southern Pacific region—excluding Antarctica and South America—and the northern region, including the adjoining Asiatic and American coastal areas, are mainly as follows: There are in the southern region no Proteocephala except three aberrant genera of somewhat dubious proteocephalan affinities, namely, *Acanthotaenia* and *Palaia* from varanid lizards, and *Batrachotaenia* from a tree frog.

There are no difossate forms except a dibothriocephalid found by Johnson (1937) in the Australian hair-seal and identified by the writer (Wardle *et al*, 1947) with *Cordicephalus* of Antarctic, northern Atlantic and northern Pacific Pinnipedia. The only caryophyllidean is a peculiar form, *Balanotaenia*, recorded by Johnson (1924) from the Australian siluroid fish *Tandanus* and relegated usually to the family Lytocestidae whose six other genera occur in Africa, India and Indonesia. Striking, among Cyclophyllidea, is the predominance of Anoplocephalidae, of which one-quarter of the mammalian species and one-third of the avian species are restricted to this region; the predominance is chiefly one of anoplocephalines with 7 out of 22 recorded genera, 9 out of 12 species of *Prototaenia*, and 3 out of 11 species of *Paronia* peculiar to the region. There is only one of the seven known linstowine genera and none of the seven known thysanosomine genera. Striking is the absence of the marsupial-favouring species of *Oöchoristica* so well represented among South American marsupials, and the occurrence of only one of the reptile-favouring species of this ancient genus. (*vide*: Dollfus, 1932; Meggitt, 1934).

Davaineidae are not well represented in the southern region but 11 per cent of the known species of the large genus *Raillitiena* are known there, mainly in Australian and New Guinea Passeriformes. The northern region has in contrast 38 per cent of the recorded *Raillietina* species.

Lacking from the monotreme and marsupial mammals of the southern region are true Taeniidae, but Beddard (1912-1915) has recorded two somewhat doubtful taeniid genera, *Dasyurotaenia* and *Anoplotaenia* both from a specimen of *Sarcophilus harrisii* (Tasmanian Devil) in the London Zoological Gardens; Beddard believed *Anoplotaenia* to be anoplocephaline and to be close to *Oöchoristica*.

As regards other Cyclophyllidea, the southern region has no Mesocestoididae peculiar to it, no Cladotaeniidae, no Catenotaeniidae, whose absence weakens the view that *Catenotaenia* is close to the stem from which Anoplocephalidae, Taeniidae and Davaineidae diverged, whether we regard it as representing a separate family or whether we agree that it is anoplocephaline.

Of Dilepididae the southern region has peculiar to it 3 (*Clelandia*, *Bancroftiella*, *Proparuterina*) of the 34 known genera; has species of *Anomotaenia* and *Choanotaenia* in ratite birds; has only three of the known 45 species of *Dilepis*. The area shares one genus of the 14 dilepidine genera with other areas but has 2 (*Zosteropicola*, *Sphaeruterina*) of the 9 known paruterine genera peculiar to it.

There are no hymenolepidid genera peculiar to the southern region but there are about six per cent of the known species of *Hymenolepis* as contrasted with 9-10 per cent in the northern region. The relative distribution of dilepidid and hymenolepidid tapeworms in the Pacific Area as a whole thus throws no light upon the question whether the multitesticulate dilepidids followed Williston's Law and preceded the paucitesticulate hymenolepidids.

Remarkable is the occurrence of two species of *Drepanidotaenia*—a common Eurasian parasite of anseriform birds—in the Australian Black Swan.

Remarkable, too, is the distribution of the genus *Nematoparataenia*, a form so aberrant from other tapeworms as to merit the establishment by Fuhrman (1933) of a special order, Aporidea, to receive it. Of its two species, *paradoxa* Maplestone & Southwell, 1922, occurs in the Black Swan (*Chenopsis atrata*) in Australia, whereas *southwelli* Fuhrman, 1933, occurs in the White Swan (*Cygnus olor*) in Sweden. That the genus is essentially southern hemispheric is suggested by Wolffhügel's (1938) discovery of the allied genus *Gastrotaenia* in a swan in Uruguay.

Striking also to the student of tapeworm distribution is the prevalence in the southern region of Cyclophyllidea with genitalial peculiarities. Thus, of Biuterinidae, New Guinea has one (*Deltokeras*) of the five known genera. Of Acoleidae (lacking female pores) the southern region has *Acoleus hedleyi*, one of only four species known. Of Dioicocestidae (separate sexes) the region has two of the seven known species of *Dioicocestus*, one of the eight known species of *Gyrocoelia*. Of Diploposthidae (double vagina or double penis) the region has *Diplogynia oligorchis*.

Too little is known about the occurrence of Tetraphyllidea, Trypanorhyncha and Tetrabothriidae in the southern region to justify conclusions as to their age or phylogeny. There is probably a closer correlation between the southern and northern regions as regards these parasites of ancient and far-ranging hosts (selachians, whales, albatrosses) than the present records indicate. (*vide*: Fuhrmann, 1921; Nybelin, 1931; Baer, 1932; Johnson, 1935; Dollfus, 1942).

The question arises as to the conclusions that may be drawn from the peculiarities of tapeworm distribution listed above.

To the two rules which express the correlation between the phylogeny of a host and that of its parasite (*vide*: Eichler, 1940), namely, (a) Fahrenholtz's Rule: the relationship of host animals can usually be determined directly from the systematics of their parasites, and (b) Szidat's Rule: the relative phylogenetic age of host animals can usually be determined from the degree of organization of their permanent parasites, a third rule can be added, namely, (c) the phylogenetic age of parasites can be determined from the phylogenetic age of their hosts.

On these postulates, as tested by a mass of morphological, embryological and distributional data, Proteocephala have been, and still are, regarded by many helminthologists as the most primitive of present-day tapeworms. Next in phylogenetic significance would seem to be Lecanicephala, Disculicipitidea, Tetraphyllidea and Trypanorhyncha. Present-day Cyclophyllidea appear to represent an unwieldy and possibly polyphyletic assemblage among which Anoplocephalidae deserve separate ordinal rank. Davaineidae, Hymenolepididae and Dilepididae also deserve collective designation as an order. Tetrabothriidae and Taeniidae should constitute a third order. The nonfossate and the difossate tapeworms (Spathebothridea, Caryophyllidea) must be regarded as polyphyletic, the recognized families deserving separate ordinal rank.

If we test these derivatives from the three postulates by considering the evidence of geological age of tapeworm groups provided by conditions in the Australasian region certain conclusions seem permissible, namely:

(1) That Proteocephala, or at any rate the genus *Proteocephalus* itself and the collared forms recorded by Woodland (1933-1937) from South American and African siluroid fishes, are not as ancient as has been supposed, dating back possibly not later than the middle of the Tertiary Period. Consideration is worth giving to the possibility of this order being diphyletic and representing a case of parallelism in evolution, the forms in Ostariophysi having come from proto-Tetraphyllidean forms, the corallate character having been independently acquired by several, not closely related, forms, and those in amphibians and reptiles (*Ophiotaenia, Acanthotaenia*) having come from spinose, proto-acanthotaeniid, forms parasitic in ancient reptilian stocks. The occurrence of four out of eight known species of *Acanthotaenia* in Australasian varanid lizards is not without significance. On such a view, the armed proteocephalan *Gangesia*, so difficult to fit into any classificatory scheme of Proteocephala, may be explicable as being close to the stem from which *Ophiotaenia* and *Acanthotaenia* diverged.

(2) That the anoplocephaline genus *Prototaenia*, widespread among marsupials, is nearer to the base of the anoplocephalid stem than *Linstowia* or *Andrya* and may be close to the base of the cyclophyllidean stem. Baer's derivation of Anoplocephalidae from crepidobotheriate Proteocephala via oöchoristicid forms receives no support from Australasian tapeworm distribution. The aberrant genera *Dasyurotaenia* and *Anoplotaenia* may represent the steps by which true Taeniidae were derived from anoplocephaline Anoplocephalidae.

(3) That the relative absence of non-fossate and difossate forms from the Australasian Region supports the view, arguable on other grounds (predominance in northern hemispheric fishes of recent origin, brief patent life, great variability of holdfast morphology, uterine structure, segmentation and proglottisation, etc.) that, far from being nearest to the proto-tapeworm stock, as earlier helminthologists supposed, they are in reality the most recent of tapeworms and represent a polyphyletic assemblage of neotenic larval forms, derived from tetra-acetabulate tapeworms, whose adult stages became extinct or disappeared with the extinction of their primary hosts.

It seems to the writer that the speculations outlined above would justify a fuller study of the tapeworms of the Australasian Region than they have so far received.

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STUDIES ON THE MORPHOLOGY AND BIOLOGY OF *STRONGYLOIDES PAPILLOSUS*

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[*Abstract*]

Strongyloides papillosus is one of the most widespread of the parasites of sheep, but its morphology is still incompletely known and its life cycle and bionomics incompletely understood.

This paper attempts to give a complete morphological picture and to assess the role of environmental factors affecting the development of the parasite outside of the host.

ENTOMOLOGICAL ASPECTS

COMPETITION IN RELATION TO DISTRIBUTION IN SOME INSECTS OF THE WESTERN PACIFIC

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In the following I propose to offer an example of two sympatric, though closely allied and widespread insects with broadly overlapping ranges, whose distribution patterns present some striking peculiarities, which are difficult to interpret by the student of zoogeography.

The two species under discussion belong to the Odonate genus *Rhyothemis* (fam. Libellulidae). This is mainly a tropical Old World genus of fairly large dragon-flies with conspicuously coloured wings, which are sure to attract the attention of every entomologist and therefore may be considered suitable objects for future research.

One of these species, *Rhyothemis phyllis* Sulz. is of western (Asiatic) origin and ranges from Burma through the entire Malay Archipelago as far east as the Fiji islands, and in N.E. Australia southwards just into New South Wales. The second species *R. regia* Brauer, comes from the east, but owing to its scattered occurrence it is difficult to establish definitely the centre of its distribution, which seems to lie somewhere in the Moluccan area of the Indo-Australian Archipelago, between the ancient Asiatic and Australian continents. Although it is possible that they evolved in the remote past as geographical forms of some ancestral species, the affinity of the two species to one another is not closer than to other species of the same genus.[1]

As stated earlier, these two species have a wide and largely coincident geographical range; they are restricted to more or less definite—though apparently identical—habitats and, as far as has been ascertained, occur under exactly the same climatic conditions in low country.

Morphologically, however, the two species are completely separated from one another; they can be easily characterized and recognized in the field, and do not show any signs of intergradation.

So much concerning their affinity.

Like most other genera of the subfamily Trameinae, which are notorious for their colonizing faculties, all species of *Rhyothemis* have broadly expanded hind wings; their weak but often soaring flight, soft and weakly chitinized body and low specific weight are all factors which enable them to be transported passively by air currents. This renders it possible for them to overcome barriers and to colonize new territories more easily than many other dragon-flies. There is much evidence that this mode of dispersal actually has happened, and probably still goes on, in the two species discussed here.

Our two species, *phyllis* and *regia*, are characteristic of lenitic freshwater communities and breed in marshes, ponds and the littoral zone of small lakes. Their larvae are active bottom dwellers, living among the muddy rootlets of aquatic vegetation. Both species have a high reproductive potential and, as far as has been ascertained, are always very abundant in suitable localities. Breeding experiments in the laboratory under normal conditions have resulted in the fact that *R. phyllis* at least is able to complete its life cycle in 7-8 months, which is in accordance with the high biotic potential of the environment. Some evidence exists that the number of individuals in every population is subject to irregular cyclic changes, but since in every locality within the range of these two dragon-flies there is a continuous succession of broods, there are no long periods of stagnation which could be followed by phases of range expansion.

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[1] Thus, *R. phyllis* is more nearly allied with *variegata* (L.), of the Asiatic mainland, whilst *regia* is intimately connected with a sibling species, *princeps* K., which itself is differentiated into two subspecies inhabiting New Guinea and parts of North Australia. (See Lieftinck, 1942.)

Both *R. phyllis* and *regia* break up into a number of local races and hence each of them may justly be called a polytypic species. But while the races of *phyllis* are fairly well defined morphologically and geographically—at least so in the western part of its range—those of *regia* are much more difficult to keep apart. From a study of the characters of most local populations of *regia*, it has become apparent that intraspecific interbreeding as a result of continuous exchange of populations has been a retarding factor in the process of subspeciation. Owing to the very great range of variation it exhibits, the characterization of the subspecies of *regia* has become a matter of considerable difficulty. As I have shown elsewhere (3), they may be composed of a medley of hybrid forms where two or more migrating populations come in contact with one another, and it is possible to find the extreme types as well as all intermediate stages in a single local interbreeding population. However, we know of two instances where

(1) the habitat of the race seems to be sufficiently isolated to have permitted the development of genetic differences peculiar of this population; and

(2) where the race might be kept separated from others by ecological factors.

In both cases *R. regia* has formed well-marked subspecies. One of these mentioned sub (1), is *regia exul* Ris, which inhabits the Kei Islands, whilst the other, *regia chalcoptilon* Brauer, has established itself in Samoa. Both races stand more apart than the others, *chalcoptlion* at the same time being the most eastern of all *Rhyothemis* known from the Indo-Pacific area.

The geographical subspecies and the amount of variation exhibited by most insular populations of *R. phyllis* and *regia* have been discussed at length by Ris (5) and the author (2, 3). In this context these questions are of less importance

From a study of the range and habitat preference of *phyllis* and *regia*, the question arises why it is that *phyllis* has a fairly continuous range, comprising also the plains of all large islands, whereas *regia* has a scattered distribution and is strictly confined either to small islands or to marshy areas very near to the coast of bigger land masses.

Rhyothemis phyllis Sulzer.

Judging by the stability of the western races of *phyllis* and the progressive specialization of the wing-pattern in an eastward direction, one may assume that this species had its centre of dispersal somewhere on the Sundaland.

Summarizing what is known of the distribution of *phyllis* and its races one observes that

(1) on all large islands of the Malaysian subregion, including Bangka and Billiton, it is a widespread, uniform, and common insect;

(2) from the islands of the Moluccas few records are known, and with the exception of one known locality in North Halmahera, where it is fairly constant forming large colonies (*R. phyllis obscura* Brauer), the species has a scattered distribution and is not definitely known to occur in situations similar to those in which *regia* is found;

(3) in several parts of Celebes, on most islands of the Philippines, and in the lowlands of New Guinea, the various races are of common occurrence and form well-populated settlements;

(4) it has spread south-eastwards into Australia and from New Guinea has advanced as far east as the Fiji Islands, apparently forming large colonies where found;

(5) it is absent from the Samoa group of islands, which are inhabited by *regia*;

(6) it is common on all islands of the Palaus and on Guam whence *regia* is not known, but absent from the Mariannes where *regia* does occur.

Little can be suggested as to the geographical origin of *regia*. It is probably derived from the Indo-Malayan *variegata-phyllis* assemblage and hence almost certainly of more recent origin than *phyllis*. The analysis of its subspecies and the present distribution pattern of *regia* strongly suggest a centrifugal spreading from a point somewhere between Malaysia and the Papuan Region.

Rhyothemis regia Brauer.

Summarizing the distribution of *regia* and its races (see map), one notices that

(1) all western populations occur on islands fringing Sundaland (the ancient landmass, or Sunda Shelf, formed by the Malay Peninsula, Sumatra, Borneo and Java) and that none of them is found on the large islands themselves, where *phyllis* is the common species;

(2) more eastwards the colonies are scattered over various islands, preferably small ones. The great number of settlements here and the great density of the populations renders it possible that the original home of *regia* has to be looked for in the Moluccas, where it is most differentiated and from where it may have radiated in all directions;

(3) Celebes, the Philippines and New Guinea are occupied by few, partly isolated, populations. It has a very scattered and purely coastal distribution in New Guinea, where it is much scarcer than *phyllis*;

(4) no single record is known from the island groups situated east of New Guinea, except from Samoa (and Wallis I.), where it has firmly established itself;

(5) it is absent from the Carolines and Guam, but it has colonized the islands beyond these, being common on Saipan (Mariannes).

It is beyond doubt that our two species are both of them in a phase of vigorous evolution. It is also obvious that *phyllis*, having had more time to spread and to differentiate into races than *regia*, has become more stabilized throughout its range.

R REGIA BR.	R. PHYLLIS SULZ.	LOC.
	▒	BURMA
	▒	SIAM
	▒	INDOCHINA
	▒	MALAYA
▒	▒	P. WÉ
▒		SIMALUR
▒	▒	ENGANO
	▒	SUMATRA
	▒	KRAKATAU
	▒	BANGKA
	▒	BILLITON
	▒	JAVA
	▒	KANGEAN
	▒	FLORES
▒		SUMBA
	▒	BORNEO
▒		BALABAC
▒	▒	CAGAYAN SULU
	▒	LUZON
▒	▒	MINDORO
	▒	CEBU
	▒	BOHOL
	▒	SAMAR
▒	▒	MINDANAO
▒		BASILAN
▒		SANGIHE
▒	▒	CELEBES
	▒	MOROTAI
	▒	HALMAHERA
▒		TERNATE
	▒	BATJAN
	▒	SULA
▒	▒	BURU
▒	▒	AMBON
	▒	CERAM
	▒	MISOOL
▒	▒	NEW GUINEA
▒		KEI
	▒	ARU
	▒	AUSTRALIA
	▒	PALAU
	▒	YAP
	▒	GUAM
▒		SAIPAN
	▒	BISMARCKS
	▒	SOLOMONS
	▒	N. HEBRIDES
	▒	N. CALEDONIA
	▒	FIJI
▒		WALLIS
▒		SAMOA

FIG. 1.—Diagram illustrating discordant distribution of *Rhyothemis regia* Br. (left column) and *R. phyllis* Sulz. (right column) in the Indo-Pacific archipelago, arranged in geographical sequence from west to east. The presence or absence of either species is indicated by dotted or empty columns. For convenience the continental Asiatic landmass is first subdivided only into four main areas. In the few cases of joint occurrence there is usually no proof of coexistence in the same locality.

Therefore it is here assumed that *phyllis* has filled the "empty ecological niches" (Mayr, 4) before *regia* could do so, and this may explain why the latter species has established itself in so many places beyond the border line of the distributional area of *phyllis*.

In the accompanying very simple diagram (Fig. 1) a nominal list is given of three continental areas on the Asiatic mainland, and of all islands in the Malay Archipelago and western Pacific, where populations of *R. phyllis* and *regia* have been found. Dotted and empty columns indicate the presence and absence of either species.

From this diagram it is clear that comparatively few islands are inhabited by both species. In addition, it must be stressed that in many places where this has been found to be so, there is no proof that the two species actually occur in the same locality! On the contrary; in fact it has been found that

(1) in the great majority of known localities the two species are mutually exclusive;

(2) only in a single case it is certain that both species occur together (N.W. point of New Guinea), and in three others (P. Wé, Engano and Cagayan Sulu) there is no sufficient evidence that they do;

(3) in the coastal locality of New Guinea, mentioned sub (2), *phyllis* occurred in swarms, whilst *regia* was very rare.

An objection which could be made in this context against the use of the word competition is, that it is not known in what way our two species do compete. No arguments can be put forward in favour of the conjecture that *R. phyllis* and *regia* are in any way intolerant of each other during adult life, and no instances are known of mutual incompatibility between dragon-flies in the reproductive stage. It must be admitted, however, that no special attention has yet been paid to the so-called "ecoclimate", i.e., the sum total of all metereological factors within the habitat, as interpreted by Uvarov (7). No comparative study has been made of the actual habits and behaviour of the early stages. Dragon-fly larvae (or nymphs) are very sensitive as to the "make-up" of their environment. In one pond-community, for instance, up to twenty and more species belonging to different genera may live together. Competition is limited or even ruled out, on account of the fact that the nymphs dwell in different spots of the habitation, or distinct biotopes: one being a mud-dweller, another may be confined to sandspits in shallow water near the shore, a third may live between submerged water plants, and the nymphs of yet another species may seek shelter among floating algae, such as *Spyrogyra* mats.

Now, it is interesting to learn that the adults and nymphal stages of our two species of *Rhyothemis* not only are exactly similar in size—the ultimate larval instar of *phyllis* being indistinguishable from that of *regia*—but also, as a result of their affinity, very probably prefer the same habitat. So I am inclined to think that here we have an example of true competition between two closely allied species, and that their struggle for existence, wherever initiated, is being settled during the development of the nymphal stages.

The question which of the species is the most vigorous of the two, and what will be the result of the competition between *phyllis* and *regia* in coincident habitations, is very difficult to solve; but there are

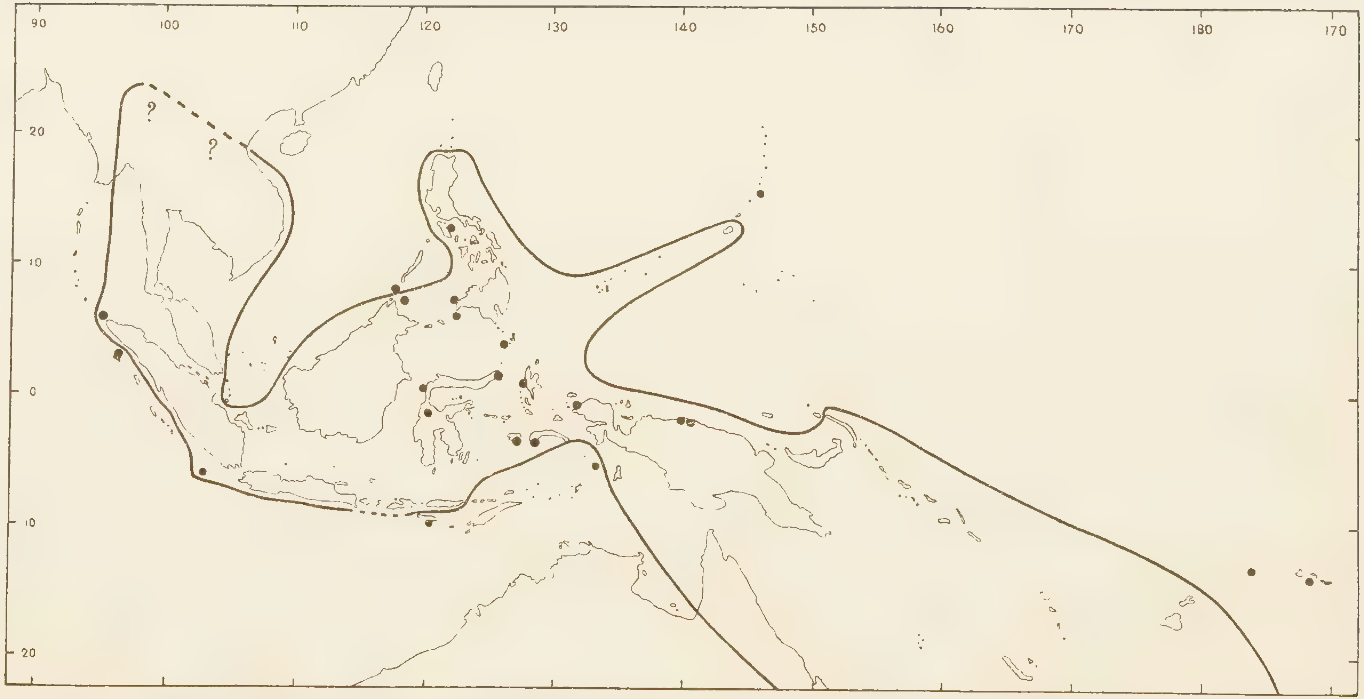

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FIG. 2.—Map of the Indo-Pacific region, showing contour of recorded range of *Rhyothemis phyllis* Sulz. and its races as compared with the scattered and peripheral distribution of *R. regia* Br. In some striking cases of insular coexistence (P. Wé, Engano, Moluccan islands), habitat segregation is presumably maintained. All known localities of *R. regia* are indicated by black dots, the range of *phyllis* by a continuous line.

indication that the latter might be able to establish itself only in those localities where *phyllis* has not, for some reason, succeeded in getting a footing.

SUMMARY AND CONCLUSIONS

Evidence put forward in the present paper shows that competition may play an important role in the configuration of the distribution pattern of certain insects. The paper deals with two allied, polymorphic species of the libellulid dragon-fly genus *Rhyothemis*, which have great potential powers of dispersal, occurring in the Indo-Pacific archipelago.

An analysis of the geographical distribution and the variability of these species suggests, firstly, that the range expansion and "normal" differentiation into subspecies of the one species (*regia*) is repulsed by the presence of another species of the same genus (*phyllis*) with apparently similar habitat preference; and secondly, that *phyllis* is more advanced and stabilized as to the forming of races, whereas *regia* is of more recent origin and in a more incipient stage of subspeciation.

Some evidence exists that *regia* has greater faculties to overcome ecological and geographical barriers than *phyllis* (probably also by involuntary dispersal), which results in a continuous interbreeding of its populations. Moreover, *regia* has not succeeded to extend its range in an orderly fashion in any direction, as most suitable localities are already occupied by the other species. The result has been a scattered distribution, partly within and partly beyond the limits of the range of *phyllis*.

The most striking points of interest are the following:

(1) the two species are in a high degree mutually exclusive within the area of overlap, although their behaviour and habitat selection are seemingly identical;

(2) small peripheral islands outside the area of overlap and outside the distributional area of *phyllis* are occupied by dense populations of *regia*;

(3) it is in such geographically isolated islands that the process of subspeciation of *regia* is most advanced.

From these data it may provisionally be inferred that the phylogenetically "youngest" species, viz., *regia*, is forced to jump over the ecological niches already occupied by the older species and that the formation of subspecies of *regia* is most likely to be accomplished in the few empty niches still left within the distributional area of *phyllis*, or outside the range of that species.

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Discussion

Dr. Salmon asked the author whether he considered selective feeding could be the mechanism which resulted in competition between the two species. Mr. Lieftinck agreed that this was a possibility, but considered it unlikely since dragon-fly larvae were not selective feeders. This had been confirmed during breeding experiments with *R. phyllis*, but he agreed that detailed investigation of the food of both species was desirable and might clarify the mechanism of competition.

TWENTY-FIVE YEARS OF MIGRATION OF THE PAINTED LADY BUTTERFLY, *VANESSA CARDUI*, IN SOUTHERN CALIFORNIA

By Charles H. Abbott, University of Redlands, California

[*Abstract*]

In twenty-five years, there have been four spring migrations of the painted lady butterfly, *Vanessa cardui*, in southern California, in the years 1924, 1926, 1941, and 1945. The observations have covered a migrating path, from the Mexican border 225 miles northward, with a breadth of 275 miles from the Pacific shore to the Colorado River. Volunteer observers in all parts of the territory have co-operated.

The studies have established:

(1) Time relations. Each migration period lasted nearly two months and showed a succession of increases and decreases with three maxima. The maxima were irregularly distributed, and appeared to be related to weather conditions. Flying occurred during the sunny hours of the day, and almost ceased during cold, rainy periods.

(2) Direction of flight. The butterflies fly in a straight line, usually north-northwest, regardless of topography, keeping a few feet above the ground, and rising over obstacles. The flight is usually against the wind, but is just as controlled when the wind comes from a different direction.

(3) Relation to vegetation types. Most of the territory in which the migration was studied is the California type of semi-desert known as brush or chaparral. But at least part of the destination is the comparatively high altitude Mohave Desert, and part of the origin appears to be in the low Colorado Desert. Vegetation types do not determine direction of flight.

(4) Theories of causation. The type of migration, large numbers at irregular intervals, is typical of the migrations of those insects and mammals which make a non-returning migration in a predictable direction at irregular intervals. Chapman's application of the "pressure of population" theory is shown to apply to this migration and is given as the only current hypothesis.

(5) It is suggested, as a recommended basis for experimental study, that this butterfly may be responsive to slight changes in temperature or humidity, and that one or both of these might be a factor in determining direction of flight.

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DISCUSSION

In the absence of Dr. Abbott, the paper was read by Dr. Karl P. Schmidt. Dr. van Steenburg asked whether the direction of migration of *Vanessa cardui* was always the same. Dr. Schmidt said that this was so and that it was a typical non-return migration. Enlarging on this he defined modern terminology indicating that the term migration was increasingly restricted to return migration and that occurrences similar to those outlined in this paper were now termed emigration exodus or non-return migration. Such distinctions were particularly necessary in the interests of clarity.

THE PHYLOGENY OF THE PAPILIONIDAE

By EUGENE MUNROE, McGill University, Montreal

ALTHOUGH the Papilionidae or swallowtails are one of the best-known groups of butterflies from the standpoint of species and subspecies identification, their higher classification has received comparatively little attention, and remains poorly understood. The Papilioninae, particularly, in which the vast majority of species are included, but in which there are few conspicuous structural characters suitable for use in classification, have been arranged in a series of species groups, whose fundamental relationships have not been seriously studied. Although the three major divisions of the old genus *Papilio* were recognized by Haase as early as 1893, Rothschild and Jordan's promised generic revision never appeared, and progress was negligible until Ford in 1944 combined his new biochemical characters with a collation of the already published structural characters to make the first approach to a rational classification.

In the course of a study of the relationships of the West Indian Papilionidae, I encountered certain features, particularly in the male genitalia, but also some larval and food-plant characters called to my attention by Dr. Wm. T. M. Forbes, which have led me to modify and amplify Dr. Ford's scheme in several respects. The detailed morphological data will not be presented here, but those findings which have a bearing on the zoogeography of the Pacific countries will be briefly discussed.

Of the four subfamilies of the Papilionidae recognized by Ford, two, the Parnassinae and Zerynthiinae, are virtually confined to Holarctica, and have little interest for us. A third, the Baroniinae, are represented by a single relict species in Mexico. In the largest subfamily, the Papilioninae, however, we find relationships which are of the greatest zoogeographic interest, and these we may consider more fully.

On general grounds it is probable that the Papilionidae arose from very primitive Hesperioidea. It is accordingly interesting to find that in that group the larvae of the Australian *Euschemon* and of certain Ismeninae feed on Lauraceae, one of the ancestral food plants of the Papilionidae (Forbes, 1932). In these same species the pupa is suspended from a twig by the cremaster and a silken girdle, in typical Papilionid fashion. This suggests that the primitive larva of the Papilionidae was smooth and green, like those of the Hesperioids, and not of the red-tuberculate type as supposed by Ford. Red segmental spots must have appeared early, however, as they or their equivalent are found in all the major groups.

The male genitalia provide the next significant clue to relationships, and with their aid the numbers of tribes of Papilioninae can be reduced to three, from the five proposed by Ford, his Cressidini going to the Troidini, and his Teinopalpini to the Graphiini. In the most primitive Graphiini the genitalia are quite normal, the ninth and tenth tergites being well developed, and the socii present, although fused with the tenth tergite to form a trifid structure. Within the tribe, however, the ninth and tenth tergites become greatly reduced and membranous, leaving the socii or their rudiments as relatively strong structures on either side of the membranous tergal area. This development allows us to recognize two subtribes. The more primitive one includes all the New World Graphiini, which I provisionally recognize as a single genus, *Eurytides* Hübner, together with the two aberrant Old World genera *Lamproptera* and *Teinopalpus*. Curiously enough, the most primitive genitalia occur in *Lamproptera*, in spite of its remarkable wing form and venation, which are doubtless associated with its unusual hovering flight. The more specialized subtribe includes all the remaining Old World forms, with the exception of the Australian *leosthenes*, which retains a well-developed tenth tergite, and which I refer tentatively to *Eurytides*. This second subtribe may for our purposes be divided into two genera: *Dabasa*, with two Indo-Malayan species, and the large genus *Graphium*.

The Papilionini show marked similarities to the Graphiini in the arrangement of the tarsal spines, in the pattern of the more primitive species, and in the appearance and lauraceous food plant of the more primitive larvae (e.g., *glaucus* group, *homerus* group). Although the dominant food plants of the Graphiini are Anonaceae, a number of species in several groups share the lauraceous food plant with the basal Papilionini on the one hand and the most primitive Hesperioidea on the other. The Papilionini are more specialized than the Graphiini in having lost the scales of the antennae and tarsi, and must accordingly be the filial rather than the parent group.

The structure of the male genitalia suggests that the Papilionini arose from the higher Graphiini at a point near *Dabasa*, for in such forms as *Papilio troilus* a membranous remnant of the tenth tergite is flanked by heavy socii much as in that genus or in the most primitive species of *Graphium*. Although certain phyletic lines are recognizable in the Papilionini, there are not enough clear-cut characters to allow us to divide the group into genera.

The Troidini are of uncertain affinities. Their male genitalia are more specialized than those of the Graphiini in showing reduction of the ninth and tenth tergites comparable to that of the Papilionini, but the tarsal spining is more primitive, and the fleshy-tubercled, *Aristolochia*-feeding larva is decidedly different. The larval characters would suggest an affinity with the Zerynthiinae, but the adults are very different in structure. Both genitalia and external structures suggest that *Cressida* from Australia and *Eurytides* from Patagonia are the most primitive Troidines. From this basal group we may derive on the one hand the New World genus *Battus*, and on the other hand the large Tropical American, Indo-Australian, and Malagassic complex which includes the closely related genera *Troides* and *Parides*.

Forbes (1932) has advanced evidence which suggests that the Papilioninae arose and their main tribes were already differentiated not later than the early Cretaceous. It is probable, therefore, that all three tribes were able to become generally distributed in the late Cretaceous—early Eocene period of broad continental connections. The interrelationships of the tribes are accordingly of little significance from the standpoint of present geographical distribution. Relationships within the tribes are, however, of considerable zoogeographic interest, for there are signs of important regional evolution within each tribe.

Thus, the Graphiini are represented in the New World only by the more primitive forms in which the ninth and tenth tergites are still clearly recognizable. The single Neotropical genus, *Eurytides*, has radiated into a large number of species some of which, e.g., the *lysithous* group, have entered native Neotropical mimetic associations. In the Old World, on the other hand, this primitive subtribe has largely been replaced by the more advanced forms, chiefly of the genus *Graphium*. There are only three remnants of the more primitive groups: the taxonomically isolated *Eurytides leosthenes* in Australia, the aberrant *Teinopalpus* in the mountains of south-east Asia, and *Lamproptera* in Malaya and the East Indies.

The large genus *Graphium* itself shows regional phyletic trends. There are two principal subgenera, one with simple valve structure, including the primitive *codrus-weiskei* complex in Australasia and also the *sarpedon-eurypylus* group, which was probably originally Asiatic, having spread secondarily to Australasia. The other large subgenus is characterized by a very complex valve armature, including a spinose patch on the dorsal margin. This subgenus has a primitive section in Africa, into which all the superficially very diverse African species fall, and in which the dorsal spines of the valve are hardly more than enlarged setae. The Asiatic section, including the *antiphates* and the mimetic *macareus-wallacei* groups, is more advanced, having a dense patch of thick spines on the valve. The Palearctic *podalirius* and *eurous* groups differ in genitalia from each other and from both of the large subgenera, and appear to represent independent evolutionary trends.

In the Papilionini, broad relationships are less easy to determine. The genitalia vary considerably, but rather erratically, and chiefly in superficial characters, so that good grouping criteria are scarce. The larvae and food plants give further information, but are not as fully known as could be wished. Space does not permit a detailed exposition of the probable relationships, but the following are the salient zoogeographic features.

In the Neotropical Region there are two lines of development, one typified by *P. thoas,* the other by *P. homerus*. Each line shows a basic relationship to Old World forms, but each has clearly followed an independent course since arriving in the Neotropics. In the Nearctic Region there are also two main groups, the endemic and probably primitive *glacus-troilus* complex, and the Holarctic *machaon* group, which appears to be of Old World origin.

In the tropics of Asia there are several major groups, the relationships of some of which are obscure. The small *schmeltzei* group, from islands of the south-west Pacific, has larvae of a remarkably synthetic type, combining characters of at least three other groups. The large Asiatic *polytes* complex is represented in Africa by a few species of the *demoleus* group, but most of the African *Papilios* belong to an allied, but endemic, segregate.

The Troidini differ sharply from the other two tribes in feeding almost without exception on *Aristolochia.* They are absent, with their food plants, from Africa, with the exception of a single species, *Parides antenor,* which has transferred to Combretaceae and survives in Madagascar. The two very primitive genera, *Cressida* and *Euryades,* have a relict distribution in Australia and temperate South America, respectively. The very distinct genus *Battus* is Neotropical, with one species extending to North America. *Parides* Hübner (the name antedates both *Atrophaneura* Reakirt and the preoccupied *Polydorus* Swainson) is widely distributed, occurring through South and Central America, from tropical Asia to Australia, and in Madagascar. The South American groups have evolved quite independently of the Old World ones, and are more primitive, the females of some species retaining the copulatory seal which is also found in *Cressida, Euryades,* and the Parnassiinae and Zerynthiinae. *Troides* is a minor segregate of the Old World group.

These distribution patterns are in their major outlines very clear and remarkably consistent. In each tribe there has been a long Neotropical development, independent of that in the Old World. In two of the tribes the Neotropical forms are demonstrably more primitive than the dominant Paleotropical groups. In the Graphiini aberrant relicts of the primitive type are still recognizable in Asia and Australia. In view of the inferred age of the subfamily as a whole it is reasonable to suppose that the extensive Neotropical development corresponds to the early-and mid-Tertiary isolation of the South American continents, which is known to have permitted the evolution of an extensive endemic mammal fauna; the retention of primitive features is to be expected in groups native to that long-protected continent.

The African fauna is quite independent of the South American one —an argument against any Tertiary land bridge or Wegenerian connection, and shows a much closer affinity with the existing Asiatic fauna. In both Graphiini and Papilionini most or all of the African species belong to a single extensively radiating side-branch of one of the existing Asiatic groups. In the Graphiini, and possibly in the Papilionini, the African group is not so advanced structurally as is the corresponding Asiatic one. This, coupled with the evidence of extensive subsequent differentiation, would suggest a rather early (probably mid-Tertiary) separation of the African and Asiatic stocks.

The distribution of the relict groups is of some interest. Of eight conspicuous relict groups in the Papilioninae, one-half occur in peripheral areas: *Cressida* and *Eurytides leosthenes* in Australia, the *Papilio schmeltzei* group in Pacific Islands, and *Euryades* in temperate South America. Three of the four others are confined to mountainous or temperate regions: the *Papilio glaucus* complex, *Dabasa,* and *Teinopalpus* (cf. also *Baronia*). Only *Lamproptera* occurs in the full tropics of the Oriental region.

Obvious limitations have prevented the presentation at this time of the full morphological evidence for these phylogenetic and zoogeographic conclusions. I hope soon to be able publish this evidence in greater detail and from a more strictly taxonomic standpoint. Meanwhile, I wish to express my very great debt to Dr. Wm. T. M. Forbes, of Cornell University, with whom I have spent many fruitful hours discussing Papilionid phylogeny, and who has contributed a number of most valuable suggestions and criticisms, which have aided materially in the completion of the present study.

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MELANISM AND SIZE IN RELATION TO CLIMATE AMONG NEW ZEALAND INSECTS

By J. T. Salmon, Dominion Museum, Wellington

In this short paper I wish to draw attention to a phenomenon which I have noticed among insects in certain wet areas of the mountain regions of the South Island of New Zealand.

During the course of several expeditions to the Hollyford-Homer areas of the southern mountains I was particularly interested in the deep and rich colouring which was apparent among insects occurring there, most noticeably among the Lepidoptera, which are familiar species on the lowlands also.

The Homer is one of the wettest places in New Zealand, averaging 285 inches of rain per year and often reaching to over 300 inches. Situated at 3000′ it is surrounded by immense heights of rock and high mountains with perpetual snowfields.

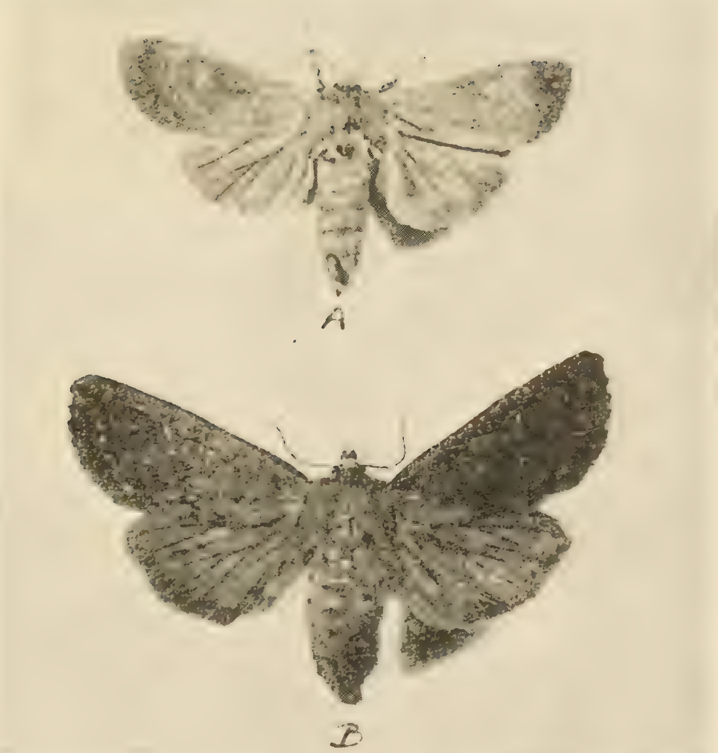
This tendency towards melanism among insects in wet places is not a new discovery, as it was noticed as far back as 1885 by Lord Walsingham, under similar conditions, among arctic and alpine Lepidoptera in the Northern Hemisphere. In 1913 Hudson drew attention to the same phenomenon occurring in New Zealand. However, under New Zealand conditions, at the Homer this tendency to melanism is accompanied by a remarkable overall increase in size of the individual insects in almost all cases. So far as I am aware, this increase in size has not been generally commented on before, though Howes, in 1944, did remark on it in another sense when writing on the synonymy of the moth *Metacrias huttoni*.

As an example of what I mean, consider a well-distributed species such as *Aletia nullifera*, which occurs both on the lowlands and on the mountains. The average wing span of 14 lowland specimens is 59.2 mm., while the similar measurement for 22 specimens taken at 3000′ - 3500′ at the Homer Tunnel is 62.6 mm. The lowland forms of the moth are a light-fawn colour; but the Homer form is dark-grey, sometimes approaching a grey-black. Similarly, the day-flying *Declana* *glacialis* from normal mountain regions averages 29.7 mm. wing span for 22 specimens; while 16 specimens from the wet Homer District average 34.1 mm. wing span, representing an increase of approximately 15 per cent in wing span, and their colour is much more intense and darker than that of the smaller specimens. From the numerous cases of this that I have noted at the Homer, I have selected four examples in addition to the two just mentioned. Among the Noctuidae, *Melanchra dotata* exhibits decided melanic tendencies, some specimens becoming a deep blackish-brown. *Ichneutica ceraunias* also shows striking melanic forms and both species exhibit marked increase in size. *Metacrias huttoni,* one of the Arctiidae, shows a marked variation in size and depth of colour. As an example of the same phenomenon among Neuroptera I would draw attention to *Megaleptoperla grandis,* in which specimens from the Homer with 63 mm. wing span are as much as 19 mm. greater in wing span than specimens from the type locality.

In discussing the phenomenon of melanism, Lord Walsingham suggested that a dark insect on emergence from the pupa would be able to absorb heat more rapidly and thus harden its wings and be ready to fly, mate, and deposit eggs sooner than would a pale-coloured species—an obvious advantage in areas of inclement climate. Hudson, on the other hand, regarded melanic colouring as a form of protective resemblance in which the insects are endeavouring to match the darker colour of their wet surroundings. He based his theory on the obvious fact that rock and vegetation assume a much darker hue when it is wet. Howes, discussing the relatively much larger size of *Metacrias huttoni* specimens from the Homer, regarded the climate as primarily responsible. Being severe it allowed time for only one brood each season, and, therefore, the caterpillar being able to feed for a longer period produced larger and brighter moths.

New Zealand possesses excellent instances of black or almost black-coloured mountain Lepidoptera among the genera *Erebia, Orocrambus* and *Tauroscopa,* and Walsingham's explanation of melanism being a heat-absorbing artifice may be correct in these cases. With regard to the phenomenon I have noted from the Homer, where partial melanism is accompanied by an increase in size, I am of the opinion that humidity is more likely to be the controlling factor.

The Homer, as I described before, is like a huge basin walled in by high mountains. It is sheltered from winds of high velocity, and there is scarcely a day when rain does not fall at some time during the twenty-four hours. Consequently, there is an abundance of water, plants grow luxuriantly, and though the climate as a whole is severe, the basin being rather sheltered warms up quickly when the sun is shining. The relative humidity, therefore, should be above normal for localities at similar elevations. We know that humidity is an important controlling factor in the development of insects; and I suggest that it is the controlling factor in producing these superlative specimens of Lepidoptera at the Homer. Occasionally, one meets with similar specimens in such places as Arthur Pass, Mount Arthur Tableland, and Mt. Egmont, all of which are wet places whose topography suggests that they may contain small areas of higher humidity. In none of these localities, however, is this phenomenon so common or so consistent as at the Homer.



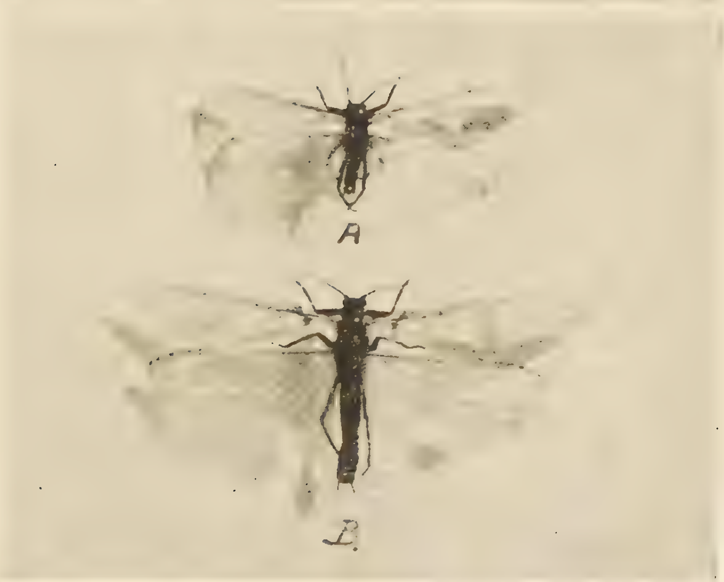


FIG. 1.–*Aletia nullifera.* (A) Typical lowland specimen. (B) Typical Homer specimen.

FIG. 2.–*Megaleptoperla grandis.* (A) Normal specimen. (B) Typical Homer specimen.

My explanation based on relative humidity is somewhat confirmed by the wet and dry season forms of certain Lepidoptera found in wet areas of the Tropics; and it would indeed be interesting to learn whether this phenomenon I have outlined has been found occurring amongst insects in other areas of the Pacific Region under similar conditions to those that I have outlined as ruling at the Homer.

DISCUSSION

Mr. Lamb pointed out that there was strong melanism induced in clothes moths fed on a diet containing blood and yeast and suggested that diet might be another factor inducing melanism. Size of adult moths was known to be a function of length of larval life and conditions in the Homer Valley would tend to prolong the larval stage. Dr. Salmon agreed that both diet and length of larval life were factors to be considered and instanced the case of *Metacrias huttoni* in the Homer District where there was one generation instead of the two on the lowland. Mr. Gourlay commented that diet might be an important factor in determining both size and colouration, and outlined the position regarding the common tussock butterfly, *Argyrophenga antipoda*, in which males were larger and lighter in colour than females in all parts of New Zealand except the Dun Mountain mineral belt, where both size and colouration of the sexes were similar. Both sexes in the Dun Mountain Region are of a colour intermediate between typical males and females.

Mr. Spiller referred to a similar melanism in specimens of *Odontria striata* from mountains. In this case it was associated with small but consistent changes in the male genitalia, perhaps indicative of incipient speciation. Dr. Salmon said that no examination of the genitalia in these insects had yet been made.

SYMPOSIUM ON ECONOMIC ENTOMOLOGY: QUARANTINE PROBLEMS AND BIOLOGICAL CONTROL

REPORT OF THE STANDING COMMITTEE ON ECONOMIC ENTOMOLOGY

INTRODUCTION

By C. E. PEMBERTON, Chairman of the Standing Committee

DURING the space of nearly ten years since the last Congress of this Association, economic entomology within Pacific regions has undergone many changes. Incident to the war economic entomology in some countries has been almost at a standstill for a time. In the Philippines devastation was so great that essential libraries and equipment which have been built up over the years are gone. Reference collections with notes, records and unpublished data, which have accumulated through patient work over a long period of time, have been burned. Much of this can never be replaced but a fresh start is being made. Economic entomology in Java has also felt the heavy impact of the war. The vast ocean territory of Micronesia has been receiving entomological attention on a scale far beyond anything in the past and has also been affected in many ways by the recent conflict. The former Federated Malay States and Straits Settlements, Japan, Formosa, China, all of the Dutch East Indies and even the Territory of New Guinea have suffered severely in the advancement of this subject. In other regions lying outside the direct line of combat rapid strides have been made in economic entomology, particularly in the field of insecticides both during and since the war.

In view of the above it has been deemed appropriate for the Standing Committee to review as far as possible the present status of economic entomology in Pacific countries with respect to their current problems, activity and progress and to summarize salient features of their work since the last Pacific Science Congress. For purposes of clarity and economy the members of the Committee have been requested to prepare their reports as concisely as possible. Their cooperation in the preparation of the following report is greatly appreciated.

ECONOMIC ENTOMOLOGY IN HAWAII

By C. E. PEMBERTON, Hawaiian Sugar Planters' Association, Hawaii

PERSONNEL

INSTITUTIONS in Hawaii employing entomologists directly or indirectly for economic purposes consist of The Hawaii Board of Agriculture and Forestry, The U.S. Bureau of Entomology and Plant Quarantine, The University of Hawaii, The Hawaii Agricultural Experiment Station, The Hawaiian Sugar Planters' Association, The Pineapple Research Institute of Hawaii, The Bernice P. Bishop Museum, The U.S. Public Health Service, The Territorial Board of Health, The U.S. Army, and a number of private companies commercially engaged in insect extermination for the general public. With a total population of only 540,500, over 50 entomologists are employed in economic work in Hawaii. This indicates the need for such service as well as the progressive state of the community.

New Insects Since 1939

During the past decade Hawaii has experienced a tremendous increase in overseas traffic by ships and aircraft. Throughout the war period this was colossal. Owing to such traffic the opportunity for new insects to become established in the Territory was greatly enhanced. Forty-seven species of insects which are definitely new to Hawaii have been found established since 1939 and 43 of these were first seen since August, 1944. These are listed below, including the dates when first seen and their probable source.

	Probable Source	*Date*
Iridomyrmex humilis Mayr. (Formicidae)	California	1940
Megamelus angulatus Osborn (Delphacidae)	U.S.A. mainland	1941
Eucelatoria armigera (Coq.) (Tachinidae)	U.S.A. mainland	1942
Graptostethus manillensis (Stal) (Lygaeidae)	Philippines	1942
Philaenus spumarius (Linn.) (Cercopidae)	U.S.A. mainland	1944
Achaea janata (Linn.) (Noctuidae)	Guam	1944
Caenis sp. (Ephemeridae)	Unknown	1944
Chironomus sp. (Chironomidae)	Unknown	1944
Anacamptodes fragilaria (Grossbeck) (Geometridae)	California	1944
Metioche vittaticollis insularis Sauss. (Gryllidae)	Samoa	1945
Eurytoma sp. near *arachnovora* Hesse (Eurytomidae)	Unknown	1945
Amyna natalis (Walker) (Noctuidae)	Fiji	1945
Polydesma umbricola Boisduval (Noctuidae)	Guam	1945
Polemistus luzonensis Rohwer (Sphecidae)	Philippines	1945
Rhipidius pectinicornis Thunberg (Rhipiphoridae)	South Pacific	1945
Paraidemona mimica Scudder (Acrididae)	Texas	1945
Euxesta sp. (Otitidae)	Guam	1945
Elaphria nucicolora (Guen.) (Noctuidae)	Texas	1945
Dacus dorsalis Hendel (Trypetidae)	Saipan	1945
Xylotrechus colonus Fabr. (Cerambycidae)	U.S.A. mainland	1945
Eumenes latreillei petiolaris Schulz (Eumenidae)	New Guinea	1946
Liris aurata (Fabr.) (Larridae)	Philippines	1946
Eumenes campaniformis (Fabr.) (Eumenidae)	New Guinea	1946
Eumenes pyriformis philippinensis Bequaert (Eumenidae)	Philippines	1946
Phytomyza spicata Malloch (Agromyzidae)	Guam	1946
Tachysphex bituberculatus Cameron (Larridae)	Philippines	1946
Volucella hoya Curran (Syrphidae)	South Pacific	1946
Volucella dracaena Curran (Syrphidae)	South Pacific	1946
Chrysobothris sp. (Buprestidae)	Philippines	1947
Chalybion bengalense (Dahlb.) (Sphecidae)	Philippines	1947
Leucospis affinis Say (Leucospididae)	U.S.A. mainland	1947
Lygus elisus Van Duzee (Miridae)	California	1947
Frankliniella minuta (Moulton) (Thysanoptera)	California	1947
Monotoma sp. (Monotomidae)	U.S.A. mainland	1947
Tenebrionid Beetle Undetermined (Tenebrionidae)	Unknown	1947
Melanolestes picipes var. *abdominalis* (H.-S.) (Reduviidae)	California	1947
Exitianus exitiosus (Uhler)—*obscurinervis* (Stal) (Cicadellidae)	U.S.A. mainland	1947
Trichoclaea postica Smith (Noctuidae)	California	1947
Hydrophilid Beetle Undetermined (Hydrophilidae)	Unknown	1947
Doliema plana (Fab.) (Tenebrionidae)	U.S.A. mainland	1947
Tenebrionid Beetle near *Palorus* sp. (Tenebrionidae)	Unknown	1947
Stictoptera subobliqua (Walker) (Noctuidae)	Guam	1948
Coriscus pilosulus (H.-S.) (Coreidae)	California	1948
Agonoxena argaula Meyr. (Agonoxenidae)	Samoa	1948
Macrosiphum luteum (Buxton) (Aphididae)	Mexico	1948
Muscina stabulans (Fallen) (Muscidae)	U.S.A. mainland	1948
Diarthronomyia chrysanthemi Ahlberg (Cecidomyidae)	California	1948
Vanduzea sp. (Membracidae)	U.S.A. mainland	1948
Graphomyia maculata (Scopoli) (Muscidae)	U.S.A. mainland	1948

Biological Control of Plant Pests

A perennial, composite shrub *Eupatorium glandulosum* HBK., which was introduced into Hawaii many years ago, is a serious plant pest in certain pasture lands. It comes from Mexico where it is heavily checked by many insects. During January, 1945, the trypetid fly *Procecidochares utilis* Stone which develops in and greatly weakens the outer branches of this plant was introduced into Hawaii from Mexico. It has become well established and is proving definitely useful in the suppression of this shrub.

Efforts to control the prickly pear cactus *Opuntia megacantha* Salm-Dyck, which now occupies large areas of pasture lands in Hawaii, are under way. At the present writing the coccid *Dactylopius opuntiae* Ckll. is under study in Southern California, in co-operation with the Citrus Experiment Station, University of California, with the object of early introduction into Hawaii. Other insects attacking *Opuntia* species are under consideration.

Control of Dengue Fever

An epidemic of dengue fever broke out in Honolulu during 1943. Under direction of the U.S. Public Health Service, in co-operation with the Hawaii Board of Health, The Chamber of Commerce of Honolulu and military authorities, an elaborate and costly campaign was waged against the mosquito vectors *Aedes aegypti* (Linn.) and *Aedes albopictus* (Skuse), resulting in the total eradication of the disease. This effort involved the systematic and intensive application of standardized methods of mosquito eradication, together with isolation of infected individuals.

New Insect Pests of Trees

During 1945 the noctuid *Polydesma umbricola* Boisduval appeared in Hawaii for the first time and caused great damage to the important ornamental and shade tree *Samanea saman* (Jacq.) Merr. Great fear was felt that this insect would kill this tree which beautifies the streets of Honolulu and other areas of Hawaii. Heavy applications of DDT sprays suppressed the epidemic and several local parasites ultimately brought the pest under fair control and most trees have recovered. In 1944 the geometrid moth *Anacamptodes fragilaria* (Grossbeck) was first observed in the Islands. Its larvae soon caused heavy defoliation of several important leguminous forage plants. However, within two years the epidemic subsided apparently owing to the activity of a number of local parasites. Several species of birds also contributed to this control. This insect came from California.

Termite Control

The two termites *Coptotermes formosanus* Shiraki and *Cryptotermes brevis* (Walker) are important economic insects in Hawaii. With the rapid increase in population in Hawaii, the unending pressure for adequate housing and the improvement in standardized methods of termite control, many companies operating as insect exterminators have in recent years established a lucrative business to fulfill the deman for control and protection against the constant ravages of these termites.

SOIL FUMIGATION

Soil fumigation on a large scale on Hawaiian pineapple plantations has been demonstrated by Walter Carter, Entomologist, Pineapple Research Institute of Hawaii, to be highly profitable. Benefit from such treatment is believed to result from the elimination of certain injurious nematodes though other factors may be involved. A compound under the name DD Mixture, produced by mainland manufacturers, has been proved by Dr. Carter to be efficacious and economically practicable as a soil fumigant in pineapple culture.

ECONOMIC ENTOMOLOGY IN GUAM AND MICRONESIA

By C. E. PEMBERTON, Hawaiian Sugar Planters' Association, Hawaii

WITH the close of the recent war the former Japanese Mandated Islands of Micronesia have been held in trust under the military government of the United States. From the beginning it was apparent that serious entomological problems were urgently in need of attention. As part of an economic survey conducted by the U.S. Commercial Company in co-operation with the U.S. Navy, two entomologists of the U.S. Bureau of Entomology and Plant Quarantine investigated insect problems in Micronesia from May through August, 1946. Their reports indicated heavy insect damage to certain important agricultural crops and remedial measures were outlined. Accordingly an Insect Control Committee of the Pacific Science Board, National Research Council, Washington, D.C., was appointed, which held its initial meeting September 30 to October 2, 1947, in Honolulu. At this meeting plans were drawn for immediate action on several specific insect problems over which the Commander in Chief Pacific Fleet requested aid. In addition to the Executive Secretary, Pacific Science Board, the Committee consisted of six entomologists representing the U.S. Bureau of Entomology and Plant Quarantine, The University of California, The Hawaiian Sugar Planters' Association, The Deputy High Commissioner for the Trust Territory of the Pacific Islands, The Bernice P. Bishop Museum and the Museum of Comparative Zoology, Harvard University, respectively. A second meeting of this Committee was held April 16, 1948, to review progress and plan further work. A brief summary of the major accomplishments which have developed from the above planning will be given.

Through co-operation with the Fiji Department of Agriculture the histerid beetle *Plaesius javanus* Ar. was introduced into Guam from Fiji during July, 1947, for control of the banana weevil *Cosmopolites sordidus* Germ. After it becomes thoroughly established in Guam this useful predator will be moved to areas in Micronesia where needed.

In March, 1947, the mirid bug *Cyrtorhinus fulvus* Knight was successfully introduced from Hawaii to Guam to effect control of the taro leaf hopper *Megamelus proserpina* Kirk. It became established and from there was moved to the island of Ponape and established.

The coccid *Icerya aegyptiaca* Dougl. heavily infests breadfruit and occasionally other plants in some of the Micronesian islands. A coccinellid, provisionally identified as *Rodolia pumila* Weise, was found associated with this scale on other islands where the pest was uncommon. This was introduced to one area where much needed. Through the assistance of entomologists of the Indian Government an undescribed *Rodolia* species was successfully introduced from India to the Majuro District of the Marshall Islands in March, 1948, for control of this scale.

The Rhinoceros beetle *Oryctes rhinoceros* L. has caused great damage to coconut trees in the Palau District of the Western Caroline Islands. Populations of this beetle have become intensified where many coconut trees were shattered by shelling during the war. Two entomologists working at Zanzibar and Mombasa, East Africa, introduced *Scolia ruficornis* F. into the Palau Islands during 1947-48. This scoliid is parasitic in East Africa on species of *Oryctes* quite similar to *O. rhinoceros*. There is no evidence to date that the introduction was successful. A third entomologist conducted an ecological study of this pest in the Palau region during 1947 and recommended certain artificial control measures. He then studied *O. rhinoceros* in the Malay Peninsula and during 1948 introduced into Palau the scoliid wasp *Scolia patricialis* Burm. subspecies *plebeja* Gribodo. Laboratory tests indicated that it would parasitize *O. rhinoceros*. It is too early to know the results of this introduction.

At Saipan, Marianas Islands, the hispid beetle *Brontispa mariana* Spaeth seriously injures coconut trees. An entomologist was assigned to study the problem at Saipan late in 1947, after which he proceeded to the Philippine Islands, Malay Peninsula and Java to investigate parasites of *Brontispa* species. Egg, larval and pupal parasites were introduced into Saipan from the Malay Peninsula or Java during the first quarter of 1948. Of these the pupal parasite *Tetrastichodes brontispae* Ferr. became established. This introduction was greatly facilitated through co-operation with Dr. J. van der Vecht, Instituut voor Plantenziekten, Buitenzorg, Java. During July, 1948, an inspection of the coconut trees at Saipan indicated that this parasite was well established and spreading.

The coconut red scale *Furcaspis oceanica* Lindinger is another serious pest of coconut on the island of Saipan. During 1948 an entomologist studied this scale on that island and found no indication of parasitism. Investigations in some other parts of Micronesia where the scale is present but uncommon revealed the presence of one or more important parasites. Two of these, undetermined at the present writing, were introduced from Ulithi Atoll to Saipan by the same entomologist. There is now indication that the introduction was a success.

The widespread shrub *Lantana camara* Linnaeus is a plant pest in many tropical regions where introduced. It was found to be spreading rapidly on the island of Ponape in the Eastern Caroline Islands. During August, 1948, four species of insects, specific to this plant and which inhibit its natural spread, were introduced from Hawaii to Ponape. These feed upon either the seeds, fruits, flower beds, growing shoots or leaves. The insects were liberated in good condition and it is anticipated that the plant will be definitely checked. These insects were the lantana leaf bug *Teleonemia lantanae* Distant, the tortricid moth *Crocidosema lantana* Busck, the plume moth *Platyptilia pusillidactyla* (Walker) (*lantana* Busck) and the seedfly *Agromyza lantanae* Froggatt.

The Giant African Snail *Achatina fulica* (Fér.) is present in great quantity in Guam and various islands of Micronesia. It has caused heavy damage to certain garden crops and other vegetation. An entomologist was sent to East Africa in December, 1948, to investigate its natural enemies. He found the carnivorous snails (Streptaxidae) *Gonaxis* sp. and *Edentulina* sp., a carabid beetle *Tefflus* sp. and a drilid beetle predatory on this and other snails. These were found by him to be important factors in Africa in the control of *Achatina fulica*. Small numbers of each were brought to Honolulu in May, 1948, and held in quarantine for further study.

In addition to the entomological surveys in Micronesia above mentioned, the Pacific Science Board secured the services of an entomologist of the Chicago Natural History Museum for a period of six months to survey the insects of the Palau District in the Western Caroline Islands and the island of Ponape of the Eastern Carolines. This survey, completed in March, 1948, resulted in the collection of some 40,000 insect specimens. Further surveys in the Marianas Islands were made about the same time by an entomologist of the U.S. Bureau of Entomology and Plant Quarantine, resulting in accumulation of several thousand more specimens for reference purposes in this area. In due time, after much material has been sorted and identified, this work will inevitably bear handsome dividends to both pure and applied science.

All insect surveys in Micronesia during recent years have strongly indicated the need for the establishment of plant quarantines within that great area. Many of the serious insect pests occur on a few of the islands and not on others. An entomologist of the U.S. Bureau of Entomology and Plant Quarantine, with experience as a plant quarantine officer, went to Guam in December, 1947, to study the general quarantine problem. After six months of study a clear cut and practical system of quarantine was recommended. Following this, the U.S. Bureau has established a branch office at Guam to administer plant quarantine regulations in co-operation with the U.S. Navy. Serving with him will be one or more entomologists also of the U.S. Bureau of Entomology and Plant Quarantine.

Finally, the Secretary of the Insect Control Committee of the Pacific Science Board has compiled a bibliography of publications on the insects of the Marshall, Caroline and Mariana Islands. This annotated and indexed list deals with some 540 titles with bibliographic reference and brief statement as to contents.

BIOLOGICAL CONTROL IN CALIFORNIA FROM 1939 TO 1949

By Harry S. Smith, University of California Citrus Experiment Station

Though the foreign introduction work was completely suspended during the war years and not resumed until 1947, biological control has been greatly broadened and some distinct advances have been made since 1939.

It was during this period that *Metaphycus helvolus*, a parasite of the black scale, *Saissetia oleae*, was mass-cultured and distributed widely throughout the citrus and olive areas. Though the parasite was introduced from South Africa in 1937, it did not manifest its usefulness until 1939. The introduction of this parasite changed the economic status of black scale from a major pest to that of a minor one.

In 1941, just prior to the war, we received from China a race of *Comperiella bifasciata,* a parasite of the red scale *Aonidiella aurantii,* and this was reared in large numbers during 1941 and 1942, and widely distributed among red scale infestations. The parasite is now established in several localities, occasionally occurring in abundance. Recent studies indicate that the good it is doing has not been fully recognized heretofore. We call this race of *Comperiella* the China strain to distinguish it from *C. bifasciata,* introduced from Japan some years earlier and which does not feed on red scale.

During the period 1943 to 1946 inclusive, a method of mass-culturing *Macrocentrus ancylivorus* was developed. This is a parasite of the oriental peach moth. The potato tuber moth was used as a laboratory host. This made possible the production of millions of parasites of this species where only thousands could previously be produced. The use of this unusual host was also found valuable in the production of other parasites, for example, *Perisierola emigrata,* a parasite of *Pyroderces rileyi*; *Cremastus flavo-orbitalis,* a parasite of the European corn borer; the green lacewing, and the egg parasites, *Copidosoma* sp. and *Trichogramma* sp. The potato tuber moth is readily adaptable to mass-culture.

The Division of Biological Control of the University of California has been broadened by the addition of a laboratory of insect pathology in order to be able to select for culture and practical use any bacterial, fungous, protozoan or virus diseases of sufficient promise. This department is manned by a well-trained insect pathologist and a staff of assistants.

A project on the control of the range weed pest, St. John's Wort, *Hypericum perforatum,* was begun in 1944, and subsequently the leaf-feeding beetles *Chrysolina gemellata* and *Chrysolina hyperici,* two European species, were imported from Australia in co-operation with the United States Department of Agriculture. These beetles were widely liberated throughout the area infested with St. John's Wort and are now established at a number of points and show promise of becoming of great value in the control of this weed menace to range land.

Our interest in the control of pest plants has recently also been directed against gorse, a most obnoxious shrubby plant from Europe now established in the Pacific Northwest, including northern California. From the first shipment of gorse insects we are holding *Apion,* a weevil, in storage through the diapause for liberation in the spring of 1949. This project is also in co-operation with the United States Department of Agriculture.

The successful growing of diaspine scales on potato tubers greatly facilitates the mass-culture of natural enemies of this group of scales. We now have cultures of a number of coccinellids and several internal parasites developing on potatoes infested with diaspine scales.

The effect of insecticides on biological control has been brought to the front as a major problem since the beginning of the war through the advent of DDT and other new insecticides. These materials in some cases locally eradicated the important natural enemies for a time and the pest then, after a generation or two, became worse than before.

A new phase of pest control which gives studied consideration to the natural enemies, the insecticides that may be used, and to cultural methods is appearing. It is already practised in California against at least one pest, the alfalfa butterfly. In this case growers are organized by districts and assess themselves a fee per acre for the employment of trained inspectors who plot the fields where parasites are sufficiently abundant to effect natural control, and the fields requiring sulphur dusting because there is none or too little parasitism present. This has been in practice for over two years and results in a great saving over the old method of treating all of the acreage.

The even-generation of hosts, wherein the time elapsed between the stages of one generation of the host and the next vulnerable to a parasite may be so long that the parasite cannot survive, is a problem that we are now trying to solve by the use of alternate host plants artificially infested in order to produce an uneven generation of the host.

An ecological study of several of our important pests and their natural enemies also is in progress with the hope that we may assist biological control by making periodic releases of insectary-reared stock of the most important natural enemies at critical periods.

The production of too many males in the mass-production of *Macrocentrus* and related insects was solved by the discovery that overmating resulted in an excess of spermatophores which interfered with the impregnation of the egg. This was corrected by providing a condition, such as subdued light or fewer males, which gives the female enough time to transfer the sperm from the spermatophore to the sperm capsule and to eject the empty spermatophore.

The discovery of host plant immunization in connection with *Cycas revoluta* and the red scale *Aonidiella aurantii* which was immunized against the parasites *Habrolepis rouxi* and *Comperiella bifasciata* (Japanese race) on this host removed the erroneous conclusion that red scale generally was immune to these parasites.

Several very important innovations in insectary operation that have been developed during this ten-year period are (1) a hot wire barrier (temperature about 180° F. more or less) around the edge of an open culture tray or box, to prevent crawling insects such as potato tuber moth larvae or ants from escaping; (2) the use of sodium hypochlorite for dissolving host cocoons, in order to free the enclosed parasite cocoon to expedite mass handling; (3) the use of a mixture of carbon dioxide and ether as a non-explosive anaesthetizing agent.

Since 1947 our foreign exploration work has been resumed with an entomologist in China and one in Africa. Though our most urgent problem is the control of citrus red scale, *Aonidiella aurantii*, our explorers are also on the watch for natural enemies of other insect pests. In the last two years we have received 81 shipments from China; 32 from Africa; and a few miscellaneous shipments from other localities.

ECONOMIC ENTOMOLOGY IN THE PHILIPPINES SINCE 1939

By L. B. UICHANCO, College of Agriculture, University of the Philippines

THE principal entities that dealt with entomology from 1939 to the outbreak of the war were this College and the Bureau of Plant Industry, in agricultural entomology; the School of Forestry of the University in co-operation with the Bureau of Forestry, forest entomology; the Bureau of Science in co-operation with this College, the Bureau of Plant Industry, the Bureau of Forestry, and specialists abroad, systematic entomology; the Institute of Hygiene of the University of the Philippines in co-operation with the Rockefeller Foundation and also the Bureau of Health, medical entomology, mainly malaria control. After the war broke out, when the Japanese occupied the Philippines, entomological work, like other scientific activities, was greatly restricted owing to difficulty of undertaking creative work under an unwelcome regime, dismissal from the service, resignation, death or loss in other ways of a number of the workers, and the cultural isolation of the Philippines from the rest of the world. The end of the war found all the entomological laboratories both in Manila and Los Baños destroyed, and the insect collections and entomological references and records burned.

Since the middle of 1945, the following entomological laboratories have been re-established, but with necessarily very meagre facilities: with myself as head and Dr. Silverio M. Cendaña as assistane head, the Department of Entomology, College of Agriculture in Los Baños; with Dr. Gonzalo Merino, chief, and Mr. Faustino Q. Otanes, assistant chief, Plant Pest and Disease Control Division of the Bureau of Plant Industry; and the malaria control section of the Bureau of Health with Dr. Antonio Ejercito as chief. I purposely did not include in this listing the malaria control unit of the U.S. Public Health Service under Dr. Francisco Dy, because it is in a class by itself as being the only entomological group that counts on ample funds, supplied from Washington. All the other entities are supported by the Philippine Government.

Since the resumption of the work, some progress has been made in the restoration of facilities, particularly in the acquisition of a number of publications which were generously sent in by experiment stations, learned societies, and individuals from abroad, especially from the United States and Hawaii. However, very many more important items of entomological literature are wanting, which makes it difficult to do satisfactory work. Our other main problem is lack of men, inasmuch as trained entomologists in the entire Philippines scarcely reach a dozen in number, with the added disadvantage that the time of the older ones are very much taken up by such other activities, important though they are, as administration, teaching, regulatory work, food-production campaigns, etc. What little progress, therefore, has been attained in entomological research more often than not was due largely to individual persistence and personal sacrifice. No funds have been allotted primarily for entomological research.

Some of the accomplishments since 1939 were:

(1) The localization of the locust outbreak centre of the migratory locust in the Philippines in east central Mindanao, which has made it possible to concentrate efforts of combating the pest in a more restricted area. Prior to this finding, the locust inspectors had been dispersed over many different parts of the Philippines, and frequently Mindanao had been overlooked.

(2) Establishment of an eleven-year master cycle for locust outbreaks in the Philippines, the peak of which apparently bore an inverse correlation with that of the sunspot cycle.

(3) Biology and methods of control of some of the more important insects of agricultural crops.

(4) Tests of insecticides under local conditions.

(5) Survey of parasitic enemies of insect pests.

(6) Survey of host plants of phytophagous insects.

Unfortunately, most of the unpublished records, particularly of the last two groups of activities, were destroyed and we are starting again from the beginning.

To my mind, a programme for fostering entomological work so far as the Philippines is concerned should include:

(1) Encouragement of more of the young men and women to make entomology a life's career through opening more positions in pertinent government services and paying salaries comparable with that of any other calling.

(2) Encouragement of visits to the Philippines by qualified entomologists from the United States and other countries through the aid of the Fulbright Act.

(3) Enabling established workers of proven ability in research to devote full time to research work and giving them compensation comparable with that received by those in administrative positions.

(4) Re-inforcement of laboratory and library facilities.

(5) Giving more facilities to investigators for conducting more field trips both within the Philippines and abroad.

(6) Facilitating better contact with other working entomologists, especially with those in the Indo-Australian areas, with which the Philippines has much in common.

AGRICULTURAL ENTOMOLOGY IN INDONESIA, 1939-1948

By J. van der Vecht, Institute for Plant Diseases and Pests,
Buitenzorg, Java.

At the outbreak of the war in Europe, nine entomologists were working in this country on insect problems of agricultural crops.

The entomological staff of the Institute for Plant Diseases and Pests (a division of the Govt. General Agricultural Experiment Station, mainly dealing with Indonesian agriculture) consisted of Dr. P. van der Goot (in charge), Dr. L. G. E. Kalshoven, Dr. C. J. H. Franssen, Dr. J. van der Vecht and Dr. P. A. Blijdorp.

In the experiment stations for estate crops the following entomologists were employed: Dr. J. G. Betrem, East-Java Experiment Station, division Central Java (Semarang): cocoa-pests; Dr. A. Diakonoff, Sugar Experiment Station (Pasuruan): sugar-pests; Dr. H. J. de Fluiter, East-Java Experiment Station (Malang): rubber- and coffee-pests; Dr. P. A. van der Laan, Deli Experiment Station (Medan) Sumatra: tobacco-pests.

Furthermore some entomological investigations were carried out in the Besuki Experiment Station (Djember, East-Java) by Dr. R. van der Veen (tobacco-pests) and in the West-Java Experiment Station, Buitenzorg, by F. A. Th. H. Verbeek (tea-pests).

In March 1942 these scientists were interned by the Japanese, with the exception of van der Goot, Kalshoven, Blijdorp and van der Laan, who were allowed to continue their work until August 1943.

In 1944 Dr. P. van der Goot died in an internment camp at Bandung, and shortly after the Japanese capitulation Verbeek was murdered. In 1946 most of the others went to Europe to recover from the privations of the interment camps. Betram, Blijdorp, de Fluiter and van der Veen accepted positions in the Netherlands and did not return to Indonesia.

Entomological activities were first resumed in January 1947 in East-Indonesia upon the return of Dr. C. J. H. Franssen, who is now in charge of the Laboratory for Plant Diseases and Pests of the newly-erected Makassar branch of the General Agricultural Experiment Station.

The Institute for Plant Diseases and Pests at Buitenzorg recommenced its work with a very reduced staff in June 1947. Entomologists now working here are Dr. L. G. E. Kalshoven (also reader in agricultural entomology at the faculty of Agriculture, University of Indonesia), Dr. P. A. van der Laan and the author (in charge). Fortunately the valuable library and insect collections of this Institute survived the war in good condition.

No entomologists are yet employed by the experiment stations for estate crops. Some of these stations were heavily damaged and suffered severe losses in material and equipment.

Shortly before the outbreak of the war in the Pacific, Dr. A. Diakonoff joined the staff of the Zoological Museum at Buitenzorg, where he is now working on the taxonomy of Microlepidoptera.

It is generally realized that the present number of entomologists in Indonesia is much too small to deal adequately with the many problems of agricultural entomology that require attention. As a consequence of the war, however, it will certainly take a few more years to supply the existing vacancies in the various experiment stations.

The results of entomological investigations, carried out or published during the period 1939-1948, will be discussed under the following headings:

1. Pests of various crops. 2. Insecticides. 3. Biological control of insects and control of weeds by insects. 4. Miscellaneous.

1. Pests of Various Crops

Rice.—The pests of rice have for a long time been the main subject of study by van der Goot. This eminent investigator has left us a series of manuscripts, mostly written during the first 1½ years of the Japanese occupation. They include a study of the results of twelve years of control of the white rice borer (*Scirpophaga innotatta* Walk.) in the Brebes district by delaying the date of sowing, a method that has proved very successful (1948); a paper on the bionomics and the economic importance of the yellow rice borer (*Schoenobius bipunctifer* Walk.) (1948); and one on the biology of the rice bug, *Leptocorisa acuta* Thunb. (to be published in 1949). Unfortunately a revision of van Heurn's general paper (Meded. Inst. v. Plz., 1923) on the pests of rice in Indonesia could not be completed.

The insect pests of stored rice demanded much attention in 1940-1941, when large quantities of rice were stored for emergency in areas that do not produce enough rice for local consumption. Considerable quantities were fumigated with CS_2 to control these pests, the most important of which were *Rhizopertha dominica* F. and *Calandra oryzae L.*

Van der Meer Mohr (1943) made some observations on the green rice moth (*Doloessa viridis* Zell.).

Coconut.—In the period 1938-1941 outbreaks of *Artona catoxantha* (Hamps.) in Central Java were successfully controlled by spraying the trees with a derrispowder-suspension in an early stage of the outbreak (v. d. Vecht, 1939). During the war the organization broke down; outbreaks were reported too late and in several cases spraying could not be carried out on account of lack of funds and materials. Some tens of thousands of trees were defoliated (such trees do not produce nuts during the next 15 - 18 months). Steps are now being taken to resume control measures as soon as circumstances will permit.

The results of a study of the factors responsible for the development of outbreaks of this pest have been briefly discussed by the author at the recent International Congress at Stockholm (see also v. d. Vecht, 1947). A more extensive paper on this subject is in preparation. Several parasites and hyperparasites of *Artona*, collected in Java, were described by Ferrière (1940) and Betrem (1941).

Tjoa (1939) gave some details of outbreaks of another coconut pest, *Hidari irava* Moore, in Java, Sumatra and Borneo, with notes on the parasites recorded from this Hesperiid.

Reyne (1947, 1948), formerly in charge of the Coconut Experiment Station at Manado (Celebes), published the results of his investigations on a serious outbreak of *Aspidiotus destructor rigidus* Reyne, which occurred in Sangi Island (North of Celebes), in 1925-1928. He concludes that the outbreak came to an end through a reduction in fertility of the females and a high death rate among the young stages, both caused by exhaustion of the food supply, rather than through the action of natural enemies.

Maize.—The maize borer *Pyrausta nubilalis* Hb. was an important pest of maize in North Sumatra in the early years of the war, when the area planted with this crop was considerably increased. Van der Meer Mohr (1943) published some notes on the life history of this insect. Van der Laan studied the possible methods of control and obtained good results by repeated dusting with a derristalc-mixture containing ± 1% rotenone.

Sugar cane.—The problem of the stalk borers of sugar cane (five species) and their parasites in Java was studied in 1939-1941 by Diakonoff (1948). He demonstrated that cane fields represent "ecological islands" into which some of the parasites that infect the borers in their wild food plants do not penetrate. *Diatraeophaga saccharalis* infects more than 25% of the borers in *Saccharum spontaneum*, but the average infection in cane fields is only 8%. Observations on the life history of some other sugar cane insects and their enemies were published by this author in 1941.

Tobacco.—Van der Laan made a detailed study of the food plants of the various lepidopterous larvae that are injurious to wrapper tobacco in North Sumatra (*Heliothis assulta* Guen., *Plusia signata* F., *Prodenia litura* L., *Psara ambitalis* Rbl. and *Phthorimaea heliopa* Low.); as a result of this work certain methods of preventive control could be recommended.

The same author demonstrated by experiments that the pseudomosaic disease, which had become very destructive shortly before the war, is transmitted by the Aleurodid *Bemisia tabaci* Genn. from *Eupatorium odoratum* L. This recently imported shrub has become a very common element of the fallow-land flora in North-Sumatra.

Van der Laan (1940) also investigated the extent of the injury caused by lepidopterous larvae that are brought with the leaves into the drying sheds. As the larvae could not be controlled by fumigation, it was recommended to pick the larvae from the leaves before they are hung up in the sheds.

The problem of protecting stored tobacco during the first years of the war from attacks of *Lasioderma serricorne* F. was solved by building the stacks of bales on wooden supports, banded with vaseline, and enclosing them in a cover of muslin. The muslin "roof" should be some inches above the tobacco and covered with paper to prevent eggs being laid upon it from which larvae can drop down to the tobacco. The sides should be at least 40 cm away from the sides of the stack. (Van der Veen, 1941.)

Gambier (*Uncaria gambir*).—The results of investigations on the bionomics and control of gambier-insects in Sumatra, undertaken by the Swiss entomologist Dr. F. Schneider in 1934-'37, were published in 1940. The most important enemies of this crop are *Oreta carnea* Btlr. (Drepanidae) and *Margaronia marinata* F. (Pyralidae).

Pepper (*Piper nigrum*).—The bionomics and control of a branch boring weevil, *Lophobaris piperis* Marsh. were the subject of an investigation by the author (1940). Four species of larval parasites were observed, but under certain conditions the control exerted by them is insufficient.

Kapok (*Ceiba pentandra*).—The last pre-war publication of the "Instituut voor Plantenziekten" contains the results of investigations on the "kapok-podborer", *Mudaria variabilis* Roepke (Franssen c. s.). The larvae of this Noctuid bore in the pods of the kapok tree and often cause considerable losses. All varieties of kapok are susceptible to the attacks of this insect. At the end of the season a high percentage of the eggs of *Mudaria* is parasitized by a species of *Anastatus*. No satisfactory control methods could be devised.

Coffee.—De Fluiter continued Betrem's work on the mealybug problem and published a detailed report (1941) of investigations on the life history, ecology and epidemiology of the coffee-mealybug, *Pseudococcus citri* (Risso). The density of the shade trees has proved to be an important factor with regard to the development of populations of this insect during the dry season. Some measures of control, based upon these studies, are recommended in a later paper (1947).

R. van der Veen studied three heavy infestations of young coffee plants by termites, in East-Java. Sprinkling sawdust with 5% Paris green around the tree-base was effective against *Microtermes*, but against *Macrotermes* better results were obtained by burying pieces of rubber soaked with a solution of paradichlorobenzene.

Rubber.—De Fluiter's paper (1941) on the Lamellicorn larvae that occur in the plantations of rubber in East-Java is a valuable contribution to our knowledge of this economically important group of insects.

It contains a key to the larvae, and notes on the life history of the various species and their Scoliid parasites. Special attention is given to the factors influencing the density of grub populations in the soil, and to the possible methods of control.

Tung nut (*Aleurites*).—Franssen (1939) published some notes on the insects recorded from *Aleurites montana* in the course of six years' observations in West-Java.

Fruit trees.—Franssen's illustrated review of the pests of the mango tree was brought up to date and reprinted in 1941. The same author published some notes on the life history of the weevil *Maleuterpes dentipes* Hollr., an occasional pest in citrus plantations in Java and Sumatra. Spraying with 0·5% lead arsenate is reported to give good control. The insects damaging the edible seeds of *Pithecolobium lobatum* and *Parkia speciosa* were studied by van der Goot (1940).

Various crops.—In 1941 ten Houten published some notes on the oviposition of *Dysdercus cingulatus* F., a pest of various Malvaceous plants, and on the feeding habits of its enemy, *Antilochus discifer* Stal.

The biology of *Zeuzera coffeae* Nietn., a pest of coffee, cocoa, teak and other plants, was studied by Kalshoven (1940).

2. INSECTICIDES

In most of the crops chemical control of agricultural pests in Indonesia is still in its infancy. Before the war lead arsenate and barium fluorsilicate were regularly used in tobacco plantations in Sumatra for the control of various species of leaf-eating caterpillars. The consumption of derris was rapidly increasing. It was mainly used for the control of thrips and Aphids (*Myzus persicae* Sulz.) on tobacco, *Helopeltis* on tea and coffee (Betrem, 1940, 1941; de Haan, 1939; Verbeek, 1942), *Plutella*- and *Crocidolomia*-caterpillars on cabbage, *Artona* on coconut palm, etc. Van der Laan (1948) found that repeated dusting with a derris-talc mixture containing 1% rotenone was effective against *Pyrausta* on maize, and that ants (*Solenopsis geminata* F.) on tobacco seedbeds could be controlled by dusting the beds with such a mixture (1941). In oil palm plantations derris was used against leaf-eating caterpillars (Limacodidae and Psychidae). Verbeek (1941) reported on the qualities of several local products, such as clays and pumice tuffs, as substitutes for talc, as a carrier for derris dusts.

After the war much interest was taken in the possibilities of the new synthetic insecticides, and DDT, BHC and others are now being tested against various pests.

Van der Laan found spraying with a suspension of DDT-wettable, containing 0·01% of the active ingredient, very effective against *Melanagromyza* and various other pests on soybeans, but recently toxaphene has given even better results. DDT gave good control of *Earias* and *Empoasca* on cotton, but heavy populations of red spider built up on the treated plants.

3. BIOLOGICAL CONTROL

Very striking results have been obtained by the liberation of *Cryptolaemus montrouzieri* Muls., which was introduced into Java many years ago, in coffee plantations in Celebes for the control of the mealybug *Phenacoccus iceryoides* Green (van der Goot, 1948).

Some other attempts, however, to establish useful insects, introduced from abroad, for the control of injurious insects in Java, have not been successful.

Franssen (1940) reported the failure of the introduction of two Scoliids, and according to van der Goot (1948), the rice borer parasite *Microbracon chinensis* Szep., imported from China, did not become established in Java.

On the other hand the first attempt made in this country to control a weed by an introduced insect, has resulted in a very spectacular success. Dense growths of prickly pear (*Opuntia nigricans*) in the Palu Valley in N.W.-Celebes were wiped out in a few years by the mealybug, *Dactylopius tomentosus* Lam., introduced for this purpose from Australia in 1934 (van der Goot, 1940).

A consignment of *Teleonemia scrupulosa* Stal, the well-known enemy of the weed *Lantana camara*, was sent from Australia to Java by air in 1939. It was intended to introduce this bug into Timor Island, where *Lantana* overgrows the pasture lands. Upon further consultation with the forestry authorities, however, the project was abandoned on account of the value of *Lantana* for reforestation purposes. Accordingly the imported colony of bugs, which had multiplied satsifactorily in the laboratory at Buitenzorg, was destroyed.

The Institute for Plant Diseases and Pests continued to give assistance in several attempts to prepare shipments of parasites for introduction into other countries. In the period under consideration Java maintained its reputation for being an important source for parasites and other enemies of various pests.

Jepson and Moutia (1939) reported that *Campsomeris phalerata* (Sauss.), imported into Mauritius for the control of Lamellicorn grubs, was established in nearly every infested cane-field. According to King (1939) and Gadd (1941), the introduction of *Macrocentrus homonae* Nixon from Java into Ceylon for the control of *Homona cofferaria* Nietn., appears to have caused a gradual reduction of this Tortricid from a major to a minor pest of tea.

The Coccinellid *Chilocorus politus* Muls., introduced into Mauritius for the control of *Aspidiotus destructor* Sign. on coconut, was reported exerting control in two districts (Jepson, 1939); the same insect proved to be of value as an enemy of *Diaspis bromeliae* Kern. on pineapple and *Chionaspis tegalensis* Zehnt. on sugar cane (Jepson, 1939; Jepson and Moutia, 1939; Moutia, 1944).

Leptomastix phenacocci Comp., introduced into Egypt from Java in 1934-'38, was reported to be abundant in Cairo, where it parasitized *Phenacoccus hirsutus* Green (Compere, 1939).

No recoveries have been made, however, of three species of Scoliids, introduced from Java into Malaya for the control of *Anomala shanica* Arr. (Corbett and Pagden, 1941). Neither has the introduction of various egg-parasites of Coreid bugs from Java into the Solomon Islands, for the control of *Amblypelta* on coconut, been successful (Phillips, 1941; Johns, 1941).

In January 1948, the Institute for Plant Diseases and Pests assisted in the introduction of *Tetrastichodes brontispae* Ferr. from Java into Saipan, for the control of the coconut leaf beetle *Brontispa marianae*.

About six months later, reports were received indicating that the parasite had become established and that the parasitism ranged from 4 to 86 per cent of the pupae.

At present attempts are being made to introduce *Spathius apicalis* Westw., a Braconid parasite of a coconut weevil, *Diocalandra frumenti* F., from Java into the New Hebrides, where the latter insect is reported to be very injurious.

4. Miscellaneous

Dr. Kalshoven's work on a new handbook on the pests of agricultural crops in Indonesia was interrupted by the war, and could not be resumed before February 1948. It is now proceeding well and the first part of the book will probably be published this year.

The same worker recently supplemented Tammes' investigations (1936) on the occurrence of swarms of the Oriental migratory locust in certain areas in the Northern part of Indonesia (Kalshoven, 1948). In most cases these swarms appear to have originated in the Philippine Islands, but additional data point to the possibility of the development of outbreaks of this insect in some of the Indonesian Islands.

At a symposium on soil fertility, held at Buitenzorg in March 1941, Kalshoven discussed the influence of the macrofauna on the soil, thereby paying special attention to termites and earthworms. Some notes on the biology of termites were published in 1941 by the same author and by Blijdorp.

In a manuscript written by the late van der Goot in 1942-'43, this worker compiled the available data on the life history, food plants, natural enemies and methods of propagation of the Indian lac insect, *Laccifer lacca* Kerr., in Java. This insect was introduced from India into Java in 1936, and has been successfully propagated here on *Schleichera trijuga* and *Pithecolobium saman*. The paper, which also contains notes on some indigenous species of lac insects, *Laccifer javanus* Chamb. and *Tachardia aurantiaca* Ckll., will be published shortly.

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NOTES ON ECONOMIC ENTOMOLOGY IN THE CANADIAN PACIFIC REGION

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The Canadian Pacific Region is defined here simply as the Province of British Columbia. Insect pest problems in this area are varied and important. Those of particular significance relate to the forests, orchards, truck crops, livestock and the protection of products in storage and in transit.

British Columbia is predominantly a land of mountains and fertile valleys. This affects transportation and limits in large measure the extent of the region that can be serviced from a single laboratory. As a consequence, a relatively large number of entomological laboratories have been established in this province: nine in all.

The brief notes that follow are presented under appropriate headings that are also indicative of the organization within the Dominion Division of Entomology.

Forest Insects

During the last ten years, forest insect outbreaks in British Columbia have been more numerous and more destructive than in the past. This is particularly true in the coastal area where the most destructive insect is the hemlock looper (*Lambdina fiscellaria lugubrosa* Hlst.). Other species of considerable importance are: the black-headed budworm (*Acleris variana* Fern.); the spruce weevil (*Pissodes sitchensis* Hopk.) and the oak looper (*Lambdina somniaria* Hlst.). In the interior, severe damage is caused especially by bark-beetles (*Dendroctonus* spp.) and by the Douglas fir Tussock moth (*Hemerocampa pseudotsugata* McD.).

All research in forest entomology is under the direction of a central laboratory located at Victoria, B.C. A sub-laboratory, at Vernon, B.C., deals with problems peculiar to the interior of the Province. Studies in biology, natural and artificial control, deterioration and salvage of injured stands form the main part of the work programme. Information on forest insect conditions is secured mainly through a systematic survey organized as a co-operative project in which the Forest Service and the industry play an important role. The field work is entrusted to 14 insect rangers who, besides making regular observations, act as regional instructors and guide the work of co-operators. All material collected and all reports made by the field personnel are sent to survey centres for analysis and study. A 61-foot boat equipped as a field laboratory is used in making surveys along the coast.

In view of the increasing importance of reforestation projects in British Columbia, special attention has been given in recent years to insects affecting forest nurseries and plantations.

Field and Garden Insects

During the period 1939-1948, considerable attention has been devoted to a study of grasshoppers (*Camnula pellucida* Scud., *Melanoplus* spp.) on the range lands of British Columbia. The biology of the more important economic species has been worked out and a most successful method of control devised which is a modification of normal range management. Definite control zones have been laid down and community baiting carried out in these under expert supervision.

Many of the insects attacking vegetable crops have received attention. Suitable remedies have been evolved covering such important economic species as the carrot rustfly (*Psila rosae* F.), the tuber flea-beetle (*Epitrix tuberus*), the pea moth (*Laspeyresia nigricana* Steph.), garden slugs (*Limax* spp.) and others. Introduced parasites are very effective against the pea moth, but the other pests are controlled through the use of the newer insecticides. These remedies have been generally accepted by the growers and have given most satisfactory results in actual field practice.

More recently, the control of certain soil infesting insects has been given attention, such as wireworms and white grubs. Research has been directed towards a study of soil fumigants, certain of the newer insecticides and to cultural practices. Some encouraging results have been secured.

The most recent problem demanding attention is the control of the insect vectors of witches' broom in potatoes. This is being investigated in co-operation with plant pathologists of the Dominion service. The study is still in the exploratory stages.

The control of insects affecting field crops and gardens is conducted from three laboratories: Victoria on Vancouver Island, Agassiz in the Fraser River Valley, and Kamloops in the central interior. The laboratory at Victoria was opened in 1945 and gives particular attention to wireworms. The other laboratories have been established for many years.

FRUIT INSECTS

Fruit insect investigations in British Columbia are conducted from laboratories at Victoria on Vancouver Island, and Summerland in the Okanagan Valley, and from a summer Field Station at Creston in the south-east interior. Increasing emphasis has been given to chemical control with comparisons of different chemicals, different formulations and different methods of application. Excellent progress has been made, in co-operation with the British Columbia Department of Agriculture, in the development of an efficient light-weight, high speed, "automatic" orchard sprayer that is likely to replace the less economical spray-gun models.

DDT has given outstanding control of codling moth but has resulted in an increase of the European red mite whose natural enemies are more subject to destruction by the DDT than are the mites themselves. Because of this complication, DDT is recommended for use only in those districts where the older chemicals have failed to control codling moth satisfactorily. However, in recent tests, a programme of alternating cover sprays of DDT and lead arsenate-oil has been found to give good control of both the codling moth and the mites.

In collaboration with Provincial extension services local spray calendars are prepared annually for the guidance of fruit growers.

INSECTS AFFECTING MAN AND ANIMALS

Investigations on insects and ticks affecting livestock in British Columbia are conducted at the Livestock Insect Laboratory at Kamloops. The main problems being investigated are tick paralysis, including the life-history and control of the tick (*Dermacentor andersoni* Stiles) and the etiology of the disease; the biology and control of warble flies; the biology and control of lice; the biology and control of sheep keds; the biology and control of mosquitoes and blackflies; and the taxonomy of fleas and their part in the spread of sylvatic plague through their native rodent hosts. In recent years, the trend has been towards increasing our knowledge of the biology of the pest species as a necessary basis for improvement in control practices.

Benzene hexachloride in a finely divided form when used as a spray or dip, has been found to be most effective, not only in destroying ticks already on the animals but as a repellent during the tick season.

Both DDT and benzene hexachloride applied as sprays at 300 pounds pressure were effective in destroying sheep keds. A single spraying kept the animals free of keds for 30 days.

Preliminary experiments indicate that feeding small amounts of benzene hexachloride to cattle gave an excellent control of sucking lice. The animals showed no ill effects from the treatment although no tests were made to determine if the meat was tained. Biting lice, poultry mites and sheep keds were not affected by feeding benzene hexachloride to the host animals.

Studies on the biology of warble flies have shown that grubs which drop in barnyard manure or stall litter that is piled with the manure, do not survive. This eliminates the necessity of treating cattle to destroy the grubs if the cattle are kept in a barnyard or confined to stalls.

A monograph on "The Siphonaptera of Canada" is now in press.

STORED PRODUCTS INSECTS

The keynote of the entomological work in connection with stored products has been prevention. Our main problem during war years was the long time storage of grain and the provision of clean facilities for its transport in order that it might reach the ultimate consumer in an insect-free condition. Success in preventing insect losses to stored grain was very largely due to the full and complete co-operation of the grain trade. Our technical staff was limited and it was necessary to depend on the grain companies themselves for much of the needed information as well as the actual carrying out of control measures.

The first entomological problem was with grain mites in the temporary storages maintained at country points throughout the grain growing area of Western Canada. The mite outbreak was controlled by fumigation and the problem was almost eliminated by the provision of adequate ventilation in the temporary storages.

The rusty grain beetle, *Laemophloeus ferrugineus* Steph., was probably the most serious insect pest of war-stored grain. These infestations arose at spots in the temporary storages both at country points and in connection with terminal elevators where moisture gained access. Once initiated, the infestations gradually migrated toward the surface, passing into dry, sound grain. Fumigation by means of deep probes acted as a holding measure until the grain could be moved and cleaned.

The Indian meal moth, *Plodia interpunctella* Hbn., was also a pest of importance in terminal elevators. The use of contact sprays and fumigation yielded satisfactory control.

A series of short courses were held at various points throughout Canada which were largely attended by selected personnel in the grain trade. Lectures, films, discussions, and practical demonstrations all played a part in training them to deal with these problems in their own plants. This educational programme was largely responsible for the excellent control work carried out by the terminal elevators throughout Canada.

The basis of insect control in transportation facilities was a thorough inspection of all boats prior to loading. This was carried out in connection with winter storage cargoes as well as boats which were carrying grain and flour overseas. Where necessary, physical cleaning, at times followed by contact sprays, and a few cases by fumigation, enabled grain cargoes to be stored and transported essentially free from infestation. The boat inspection programme proved so valuable during war years that it has now been adopted as a routine peacetime measure.

Biological Control of Insect Pests

Beginning with the transfer from New Brunswick in 1916 of the predaceous mite, *Hemisarcoptes malus* Sch., to aid in control of the oyster shell scale, the introduction and distribution of insect parasites and predators in British Columbia has proven very successful in reducing damage by a number of important pests, including apple woolly aphid, satin moth, larch sawfly, lecanium scale, codling moth, European earwig, holly leaf-miner, pea moth, greenhouse whitefly and apple mealybug. The majority of these projects were initiated prior to 1939 but subsequently expanded. Transfer of the apple mealybug parasite, *Allotropa utilis* Mues. from Nova Scotia to British Columbia began in 1939 and was so successful in reducing the pest in the Kootenay Valley that it is now being distributed in the Okanagan Valley and on Vancouver Island. The parasite *Encarsia formosa* Gahan has been used with remarkable success for nearly twenty years in controlling the greenhouse whitefly on tomatoes and cucumbers and was particularly valuable during the war. *Encarsia* is supplied to growers each year as required from the Dominion Parasite Laboratory.

Transfer of a number of introduced parasites from British Columbia to the Eastern Provinces has been made, including the larch sawfly parasites *Mesoleius aulicus* (Grav.) and *Tritneptis klugii* Ratz., the satin moth parasite *Apanteles solitarius Ratz.*, the earwig parasite *Bigonichaeta setipennis* Fln., the pea moth parasites *Ascogaster quadridentatus* Wesm. and *Glypta haesitator* Grav. Transfer of several species of native parasites of the spruce budworm not found in the Eastern Provinces is now in progess and is the most extensive experiment in the transfer of parasites within the country yet attempted in Canada.

During the present year (1948) a laboratory was established on the campus of the University of British Columbia at Vancouver to serve as a regional headquarters for biological control work in the province. This laboratory is in charge of Mr. J. H. McLeod, for many years on the staff of the Dominion Parasite Laboratory at Belleville, Ontario. The work of this new laboratory will be closely co-ordinated with that of the Dominion Parasite Laboratory and with workers in other Units of the Division of Entomology. More detailed and exhaustive field studies will now be possible and the closer contact with the problems and other workers in the province will greatly facilitate the development and expansion of the service.

SOME ASPECTS OF AUSTRALIAN ENTOMOLOGICAL RESEARCH SINCE 1939

By Frank Wilson, C.S.I.R., Canberra

It is not possible in brief compass to outline the multifarious enquiries conducted by State, Commonwealth and University entomologists in Australia during the last decade. The field will be restricted, therefore, to brief accounts of some of the more important problems investigated, though such a selection is necessarily very arbitrary. The work reviewed here was done very largely by officers of the Division of Economic Entomology of C.S.I.R.

(1) Malaria

Of our wartime entomological problems, the control of malarial mosquitoes was the most urgent task once the war approached Australian territory. In the earlier stages of fighting, against serious casualties were opposed insufficient knowledge and means for effective control.

Malarial research at Cairns, where an epidemic of benign tertian malaria was in progress, showed for the first time on the mainland of Australia that the vector was *Anopheles punctulatus farauti.* Field surveys of infection rates in mosquitoes gradually indicated the relative importance of different species and races, and eventually showed that where the Australians were operating the most important vector was *A. punctulatus punctulatus.* A firm basis for field identification was created by systematic studies of Anophelines and Culicines, while studies were also made on mosquito habits, relative avidity for human blood, and the location of breeding grounds in the field.

Earlier research on control provided "malarial oils" for use against Anopheline larvae, and for sprays against adults, and these means gave considerable control where the methods were fully applied.

Studies of repellents showed that dimethyl phthalate was effective, and this material was in full use from March, 1943.

The advent of DDT revolutionized our methods, making possible control of Anophelines with unprecedented speed. Aircraft spraying using service aircraft was then developed, the method diverging from that used elsewhere in the utilization of a very fine spray and favourable atmospheric conditions for its descent. The results were very satisfactory.

Anopheline control proved efficient in base areas and gave considerable protection to operational troops, except in very forward patrolling positions.

(2) Insect Pests of Stored Wheat

In the first world war, Australia experienced tremendous losses from pests attacking stored wheat, so that the advent of the second war initiated some intensive work on the preservation of stored wheat from insects. The problem was complicated by the vast quantities of grain held, by the great distances separating the wheat belts, and by the various methods of storage in use.

Of the gains in knowledge and control techniques made, the following were most important. Many mineral dusts of insecticidal use were investigated and some of these were shown to be comparable in efficacy with some of the better European dusts. It was also shown that the addition of DDT or Gammexane to these dusts brought them to the same level of efficiency as the best dusts produced elsewhere.

In the utilization of these dusts a considerable advance was made. It was shown that the application of mineral dust to the surface of the vast mounds of loose wheat held in bulk wheat depots greatly reduced the infestation rate. A combination of this surface dusting with the application of liquid fumigants to the wheat surface where infestations did arise gave satisfactory control when wheat was stored for several years. This method was used extensively and with considerable success in Victoria.

Another main problem was that which had caused such appalling losses in the earlier war—infestation in bag stacks. A satisfactory solution to this problem was evolved which allowed of the effective fumigation *in situ* of whole stacks of bagged wheat irrespective of the size of the unit requiring to be treated.

Apart from these and other practical advances, there was a considerable increase in knowledge of the bionomics of the more important grain pests, and of grain as an environment for insect development. Particular attention was given to the question of insect damage to wheat mounds and the reason for the restriction of insect damage to the periphery of the mound. It was shown that this restriction is caused by heat generated by the insects, a related fall in moisture content, and the consequent development of lethal conditions within the wheat mass.

This programme of research, impelled by war's exigencies, was very productive of positive results, and the general effect of the intensive work has been to improve radically the understanding of wheat storage problems in Australia.

(3) ENTOMOLOGICAL CONTROL OF WEEDS

To the field of biological control Australian entomologists have long given serious attention. To the entomological control of weeds special consideration has continued to be given, and of the problems investigated, one, St. John's wort, promises a satisfactory result. Some years of investigation in England produced a number of insects which, having passed satisfactorily through tests of their host specificity, were liberated in Australia. For several years after the first liberations no success was recorded with these British species, the failure being attributed to unfavourable climatic conditions and the activities of natural enemies. As a consequence, the centre of the field of search was transferred to southern France, where the St. John's wort fauna differs considerably from that present in England.

However, one of the British species, *Chrysolina hyperici*, reappeared in the field in Australia in 1939, having disappeared for five years after its last liberation in 1934. It has subsequently become increasingly common and has been established in most of the main St. John's wort areas in Australia.

Of the French species, two were liberated and both became established almost immediately. These insects are *Chrysolina gemellata* and *Agrilus hyperici*, a leaf-eater and root-borer respectively. *Agrilus* is the dominant insect on St. John's wort in southern France, but has so far proved disappointing in Australia. *C. gemellata*, however, has been extremely successful and has rapidly overtaken *C. hyperici* in importance. Generally, these two species occur together and have cleared quite considerable areas that had been covered by the weed for decades or even generations. The weed is usually destroyed systematically by the insects, a small cleared area gradually expanding as the beetles work on a well-defined, often circular, front. Regrowth subsequently takes place after the insects have passed on, but this is dealt with later when discovered by dispersing insects. The results already obtained have been highly beneficial, but there is no reason to think that the insects have nearly reached their peak of effectiveness. Consignments of these insects have been made both to New Zealand and the United States of America, and from both countries come reports of the insects' effectiveness.

Since the unparalleled success obtained with prickly pear, the main centre of interest in the field of entomological control of weeds has been the St. John's wort problem. However, much work has been done on other Australian weeds. With *Lantana* some limited success in northern Queensland has attended the introduction of *Teleonemia scrupulosa*. Insects have also been established against Noogoora burr and gorse, though so far without significant result. An extensive search in many parts of the world for enemies of Noogoora burr has yielded only one insect specific to the weed—*Euaresta aequalis*—so that it is doubtful if it will be safe to liberate any other insects against this serious pest plant. Two other weeds have received some attention, ragwort and nutgrass. *Tyria jacobaeae*, released against ragwort, failed to become established in the face of attacks by predators. With nutgrass again, lack of specificity in its enemies prevented liberations being made.

(4) BIOLOGICAL CONTROL OF INSECTS

In the field of entomological control of insect pests perhaps the main successes have been achieved against whitefly, woolly aphis, and the green vegetable bug. In the first two, parasite introductions (*Encarsia formosa* and *Aphelinus mali*) have very radically improved the position: in *Nezara viridula*, the establishment of *Microphanurus basalis* has proved markedly beneficial in some areas, though a still higher degree of control is necessary.

Various degrees of success have also attended the establishment of the egg parasite *Anagrus armatus* against the apple leaf-hopper; of *Habrolepis dalmannii* against golden oak scale; of *Apanteles glomeratus* and *Pteromalus puparum* against cabbage butterfly; of the giant toad, *Bufo marinus*, against beetle pests of sugarcane; and of the predatory Hydrophilid, *Dactylosternum hydrophylloides*, against the banana stem borer, *Cosmopolites sordida*. Most of these introductions have resulted in a marked diminution of the incidence of the hosts, but in few could the result be said to be adequate.

Parasites or predators have also been introduced against pine Chermes, peach moth, fruit fly, olive scale, red scale, pea weevil, cabbage moth, potato moth, grass grubs, snails, and buffalo fly. In all these no appreciable benefit has so far resulted and in most instances the beneficial insects have not become established. It is unlikely that the full possibilities of biological control have been investigated in any of these pests, so that each failure may be reversed if later work is undertaken. Some of these projects, indeed, are being pursued intensively at the present time, so that adverse judgment as to the outcome of these investigations would be premature.

(5) Termites

These insects have a very important place in Australian entomology, and have been given comparable attention. A considerable advance was made with the publication of G. F. Hill's monograph of Australian termites, which has laid a solid foundation for further work.

In the practical field, white arsenic has proved to be the most effective material for direct control of termites. The use of resistant timbers or anti-termitic materials offers an important means of reducing termite damage, and the evaluation of this natural resistance or antitermitic value is being tested in the field and laboratory. Improved techniques have been devised for these tests. An important development has been the production of standard techniques for the rapid testing of timbers. Artificial colonies of workers and soldiers, standardized as to population, the nature of the nest material, and the physical conditions of the test, measure the susceptibility of the tested material in terms of the quantity eaten and the population survival over the period of the test.

Considerable attention has been given to the biology and ecology of termites. Much knowledge has been acquired as to the physical characteristics within mound colonies, the populations of mature colonies, and the underground foraging gallery systems employed.

Present investigations comprise the compilation of distribution maps for the more important species, the evaluation of soil poisoning methods, field and laboratory testing of timbers and other materials, and colony formation and growth in some of the more important species.

(6) Locusts and Grasshoppers

Intensive work on Australian locust and grasshopper problems has continued since 1935. The relative susceptibility of different regions of eastern Australia to outbreaks of *Chortoicetes terminifera* and of areas of Western Australia to *Austroicetes cruciata*—these being the chief species concerned—has been mapped. The existence of outbreak areas has been demonstrated for *Chortoicetes* and the course of an outbreak established.

Analysis of field observations led to the determination of limits of temperature and moisture that permit multiplication and maintenance of swarm coherence, and the development of a climatic index allowed of the measurement of climatic favourability of any season or locality.

It has been shown that a number of factors are involved in the ecological characteristics of outbreak areas—climate, soil, vegetation, timber clearance, and grazing. Two distinct habitats of special significance to the biology of *Chortoicetes* are so distributed within the outbreak areas as to permit a high rate of multiplication, and a concentration of population—the two crucial conditions for the formation of migratory swarms.

Long-term field studies in progress are concerned with the possibility of altering ecological conditions in the outbreak areas so as to render these incapable of producing swarms. This work has been concerned largely with attempts to revegetate critical portions of outbreak centres with trees and shrubs. Related to this are studies on the relation between locust abundance and tree density in naturally timbered areas.

(7) SHEEP BLOWFLY

Estimated to cause losses to Australia of the order of £4 million per annum, sheep blowfly have been the object of intensive study. *Lucilia cuprina* is the most important species but *Calliphora* spp. account for 20 per cent. of strikes. By systematic trapping over an area in which large numbers of marked flies were liberated data were secured on the fluctuations of the natural population density of *Lucilia cuprina* and on the "area of search" of female flies. It appeared that very rapid fluctuations in density could occur during the course of one experiment, the rate of movement being partly correlated with meteorological conditions, and a maximum fly movement of 4·7 miles in 30 hours being recorded. Although intensive trapping reduces the incidence of strike, trapping apparently is not economic.

Struck sheep are specifically attractive to gravid females of *L. cuprina* and very much less attractive to other species: however, fresh carrion is still more attractive to blowfly. Oviposition on sheep is dependent on an adequately long fleece and the presence of a putrefactive factor. For experimental purposes indole was found to provide a very satisfactory putrefactive factor. Many materials have been tested as repellents, and a number of effective materials found.

The relative importance of live sheep and carrion as breeding grounds for *L. cuprina* was evaluated and it was found that extremely few *L. cuprina* can be bred from sheep carcasses, unless predators are prevented from attacking the primary flies. In the warmer months intense competition causes considerable mortality in *cuprina* in carcasses. On the other hand, from struck sheep large numbers of flies were produced.

Toxicological investigations have included studies of stomach larvicides, contact larvicides, and other insecticides. Several strike dressings have been produced, but while many favourable reports were received as to the B.K.B. dressing, it appears that a yet higher degree of protection is required.

A number of studies of blowfly physiology were carried out to provide background information. A method was evolved for aseptic cultivation of blowfly larvae. The pH of the gut contents of larvae and adults was determined, while the absorption, accumulation, and distribution of iron and copper has been studied, and the production and distribution of ammonia also investigated.

(8) BUFFALO FLY

The spread of buffalo fly (*Siphona exigua*) to coastal Queensland increased greatly possible economic losses, and caused the renewal of investigations. It was found that the use of the U.S. horn fly trap, or of a modification of it that had the inside glass surfaces coated with DDT, reduced fly populations by 95 per cent.

Dairy cows were protected by frequent applications of light sprays or by an occasional drenching spray. Spraying a few square feet of the hide about the shoulders is sufficient to eliminate the pest.

The control of buffalo fly on cattle that are handled regularly is now a comparatively simple matter. Where cattle are seldom mustered, buffalo fly control is still a problem.

(9) Cattle Tick

Further investigations on the complete non-parasitic and parasitic life cycle in *Boophilus microplus* showed that this could occupy over a year, and it became necessary for those in charge of the eradication campaign in New South Wales to extend the compulsory dipping period from 40 weeks to 60 weeks.

Evidence has gradually accumulated that the ticks are becoming resistant to arsenic—the standard material for dips—and it has finally been found impossible to clean infested beasts with this material. This made investigation of other insecticides necessary, and it has been found that 0·5 per cent. p-p′ DDT emulsion gives satisfactory control, besides protecting the animals from ticks for 10 days.

(10) Red-legged Earth Mite

The actual damage to pastures caused by this serious pest (*Halotydeus destructor*) was estimated. In plots free from mites, and in others showing normal and heavy mite infestations, accurate field measurement showed no significant pasture difference in the first year, a marked difference in the second, and a tremendous difference in the third. By this time subterranean clover had almost disappeared and Wimmera ryegrass had been reduced.

Many insecticides are effective against the mite, but cost of application renders their use uneconomical. Recent work has indicated that BHC and DDT may be effective if incorporated in superphosphate used in topdressing during February to March. However, the work is complicated by the fact that lucerne flea is not affected by the concentration used while its predator (the Bdellid mite, *Biscirus lapidarius*) is killed.

ECONOMIC ENTOMOLOGY IN NEW ZEALAND

By L. J. Dumbleton, Entomology Division, D.S.I.R., New Zealand

New Zealand's economy is built on the export of primary products such as butter, cheese, meat and wool. The pests of the greatest actual or potential importance are those affecting pasture grasses and clovers or supplementary cruciferous crops such as turnips, swedes, rape, etc. Most of the minor crops such as wheat, oats, maize, peas, potatoes, etc., are either relatively free from pests or have only minor pests. There is, however, the usual range of orchard and fruit pests (pip fruit, stone fruit and citrus) and the orchard industry is of necessity the largest user of insecticides in the country. Both native and exotic (*Pinus radiata*) forests are relatively free of serious primary pests and the extensive *Pinus* forests are subject to a growing risk of the establishment of serious pests. Animals are relatively free of serious pests and there are no insect transmitted diseases of man or animals.

IMPACT OF WAR

The effect of this was not great except in decreasing staff owing to absence of men in war service. Work was instituted on cheese mites owing to anticipated trouble with this pest in temporary unrefrigerated stores whose use was made necessary by shipping difficulties. The only other activity was a mosquito survey which was made because of the possibility of the establishment on Anopheline species from malarious areas in the Pacific.

PROGRESS SINCE 1939

The effort devoted to white grub (*Odontria*) research and timber insects (mainly *Anobium*) has been notably increased and as in other countries the testing of new insecticides has been an important feature.

Pasture Pests

White grub (*Odontria zealandica*). Work has commenced at the Ashburton sub-station (two officers) on the biology and ecology of this pest and the testing of an introduced nematode parasite. An officer stationed in Australia is investigating Thynnid and Scoliid parasites which may be of use to N.Z. and similar work (now discontinued) was done in South America.

Subterranean Caterpillar (*Oxycanus cervinatus*). A satisfactory control has been secured with a Paris green-bran bait. Alternative methods and materials have been investigated. These two native insects are the major pests of pasture in N.Z.

Cricket (*Gryllulus servillei*). Improved control has recently been secured with gammexane-bran baits.

Cocksfoot Stem-borer (*Glyphipteryx achyloessa*) and Clover Case Bearer (*Coleophora spissicornis*) have been investigated from the biological and life history angle.

Red Legged Earth Mite (*Halotydeus destructor*) a potential pest of subterranean clover has been kept under close watch.

Bumble bees (*Bombus*) species have been surveyed but we have been unable to secure a permit to introduce other species which might improve the fertilization of red clover.

Crop Pests

Hessian Fly (*Mayetiola destructor*) and Argentine Stem Weevil (*Hyperodes griseus*). These wheat pests have been investigated mainly in relation to the resistance of wheat varieties in connection with wheat breeding work. Parasites of the latter insect have been located in South America but no introductions have so far been made.

Diamond Back Moth (*Plutella maculipennis*) and White Butterfly (*Pieris rapae*) are the two major pests of crucifers, both field crops and garden crops. Two parasites of each have been established—*Diadromus collaris* and *Angitia cerophaga* on *P. maculipennis*, and *Pteromalus puparum* and *Apanteles glomeratus* on *P. rapae*. The results with *P. rapae* have been very good; those with *P. maculipennis* are not yet carefully assessed.

Chemical control work on Red Legged Earth Mite (*Halotydeus destructor*) as a vegetable pest has showed that effective control is secured with DDT.

The bionomics of Vegetable Weevil (*Listroderes obliquus*) and Carrot Rust Fly (*Psila rosae*) have been investigated.

Orchard and Fruit Insects

Investigations have been made on the seasonal history and biology of Codling Moth, Wax scale (*Ceroplastes*) and Dicky Rice Weevil (*Maleuterpes spinipes*). Attempts were made to introduce several parasites of Codling moth and one for Red scale of citrus. Much testing of spray materials and spray programmes has been done.

Timber Insects

Considerable work has been done on the biology and control of *Anobium domesticum*, the common house borer. Much effort has been devoted to the control or eradication of the introduced Australian termites (*Coptotermes* spp.).

Stored Products

A survey of the existing pests is in progress. Ecological and control work was done on cheese mites and practicable control measures developed using dichloroethyl ether.

Livestock Insects

Investigations have been mainly concerned with the testing of derris, gammexane and DDT as sheep dips against keds and lice.

Insects of Man

A mosquito survey of the country was carried out.

Biological Control of Weeds

The only new introduction during the period was *Chrysolina hyperici* in 1943 for the control of St. John's Wort (*Hypericum perforatum*). This has been distributed in 1946 and 1947 to other areas using material from the site of the original establishment.

The distribution of the Seed Weevil (*Apion ulicis*) for control of Gorse (*Ulex europaeus*) has been continued. The Chilean Sawfly (*Antholcus varinervis*) for the control of Piri-piri (*Acaena* spp.) has failed to maintain itself in the field though laboratory colonies survive.

Newly Established or Recently Recorded Insect Pests

The following list emphasizes the fact that the quarantine system needs tightening and also that a better insect survey and intelligence system is desirable so that eradication measures can be taken more promptly in the case of newly established pests.

Red Legged Earth Mite (*Halotydeus destructor*). A South African(?) mite occurring in Australia. Pest of clovers, vegetables and flowers. Recorded 1943.

Soldier Fly (*Metoponia rubriceps*). An Australian insect recorded in 1943. A pest of maize and (?) pasture.

Green Vegetable Bug (*Nezara viridula*). Occurs in Australia, Fiji, Cook Is. Recorded in 1944. A pest of vegetables.

European Wasp (*Vespa germanica*). Recorded 1944.

Subterranean Termites (*Coptotermes* spp.). Australian species recorded in 1939. Serious pest of house timbers, etc.

Black Beetle (*Heteronychus sanctae-helenae*). Recorded 1939. South African species occurring in Australia. Pest of maize and (?) pasture.

White Fringed Beetle (*Pantomorus leucoloma*). Occurs in Australia. Recorded 1944. Pest of Vegetables.

Wax scale (*Ceroplastes* sp.). Citrus pest. Established 1939.

FUTURE DEVELOPMENT

Work will probably be continued along the lines indicated for the past period. No drastic change in the direction of the main lines of work is anticipated. The main improvements could come from better organization and integration of organizations and from a review and improvement of the plant quarantine systems.

REGIONAL PEST FAUNAS

THE MORE IMPORTANT INSECT PESTS OF BRITISH COLUMBIA[1]

Assembled by K. M. KING from contributions by H. Andison,
E. R. Buckell, R. Glendenning, J. D. Gregson, K. M. King,
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1. INTRODUCTION

By H. A. RICHMOND and H. ANDISON
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BRITISH COLUMBIA's insect problem—like its climate, topography, forestry and agriculture—is characterized by a truly remarkable diversity. This is especially marked for the agricultural pests in the coastal region, which is further characterized by the high proportion of species that have been introduced from European or other sources.

From the air, British Columbia appears as a sea of mountains. The main structural feature is the general north-west and south-east trend of its mountain ranges and valleys, extending in some instances the entire length of the Province—some 900 miles. Although there are five distinct climatic belts, the main division is between the Coastal and Interior areas, separated by the Coast Mountains. The Coastal area is one of high precipitation, particularly in winter, and remarkably mild temperatures. In the Interior, which is generally dry, seasonal temperature extremes range from −45° F. to +105° F., in different districts.

The area of British Columbia is some 355,855 square miles—rather more than the area of the United Kingdom, France, Belgium, Holland and Denmark combined. Of this, about 32 per cent is suited only for the growing of forests, and about 2 per cent is classed as agricultural land. The gross value of forest and agricultural products in 1946 was estimated at 173,471,000 dollars and 118,588,000 dollars respectively.

Of the 4,250,000 acres considered to be suitable for cultivation, about one-fourth is so utilized at present. In addition, there is a fairly large acreage classified as open grazing land. The arable sections of the Province are widely scattered, comprising river valleys, coastal plains and inter-mountain plateaux. The most important agricultural exports are apples, other fruits and vegetables. For the continuation of these industries, effective and economical control of insect pests is vital.

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[1] Contribution No. 2583, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.

Forest conservation presents a great complexity of problems, 22 distinct forest types being recognized. Despite the enormous extent of forest growth the end of mature stands is well within sight. The total average annual depletion is calculated as follows (in millions of board feet):

Cut 3176; Insects 401; Fire 298; Total 3876.

These figures, as reported in Forest Resources of British Columbia 1945, place forest insects as the major destructive agent apart from man himself.

2. Forest Insects

By H. A. Richmond, Dominion Forest Insect Laboratory, Victoria, B.C.

Outbreaks of forest insects in British Columbia over the past ten years have been widespread and more numerous than recorded in any similar period heretofore. This may have been due to particularly favourable conditions for insects or perhaps to a better detection service in the forest insect survey.

Most important among these have been the outbreaks of western hemlock looper, *Lambdina fiscellaria lugubrosa* (Hlst.), black-headed budworm, *Acleris variana* (Fern.), false hemlock looper, *Nepytia canosaria* (Wlk.), Douglas-fir tussock moth, *Hemerocampa pseudotsugata* McD., striped alder sawfly, *Hemichroa crocea* (Fourc.), hemlock sawfly, *Neodiprion tsugae* Midd., European larch sawfly, *Pristiphora erichsonii* (Htg.), spruce budworm, *Choristoneura fumiferana* (Clen.), oak looper, *Lambdina somniaria* (Hlst.), forest tent caterpillar, *Malacosoma disstria* Hbn., spruce aphid, *Aphis abietina* Walk., Sitka-spruce weevil, *Pissodes sitchensis* Hopk., bark beetles, *Dendroctonus* spp., and ambrosia beetles.

The greatest devastation wrought through these outbreaks has been that from the hemlock looper, which between 1945 and 1947 destroyed millions of feet of mature hemlock and Douglas fir on the British Columbia coast. Concurrently it appeared over widespread areas in the Interior wet belt. Preceding its outbreak in British Columbia, large infestations occurred in the states of Washington and Oregon, a situation similarly recorded on occasions of previous outbreaks. Although the major infestation has come to an end in the current cycle, more northerly populations appeared in 1948 which may presage further infestations in the near future. Agents of natural control were for the most part diseases, including eight species of bacteria, three of fungus and one virus. Parasitism was general but in only one area was it recorded on a scale sufficient to produce any appreciable degree of control.

The infestation of black headed budworm preceded that of the hemlock looper on the coastal areas of British Columbia and appeared in outbreak intensity over Vancouver Island and the Queen Charlotte Islands between 1941-43. Only one case of severe damage was found, in an area some 10 miles square on the northern portion of Vancouver Island, where heavy tree mortality occurred. This was the first record in the Province of extensive tree killing by this insect.

The striped alder sawfly is of special interest because it is relatively new as a forest pest in British Columbia. First recorded in the Province in 1930, it has since appeared over the entire extent of the coast line and has been continually increasing in population and distribution. Current infestations by this insect are developing in areas along the mainland, in the Queen Charlotte Islands and on parts of Vancouver Island.

Coinciding with the hemlock looper attack there developed one of the severest outbreaks of the oak looper recorded thus far. The infestation has been restricted to the vicinity of greater Victoria on Vancouver Island where 100 per cent defoliation of oak has occurred during the past three years. In 1948 the pest appeared to have reached its peak population, with disease and parasitism becoming very pronounced. While total stripping of foliage has occurred over large areas, no oak was killed and none is expected to die.

The hemlock sawfly has shown a marked increase throughout the coastal area of British Columbia since 1945. Recorded in that year in the Queen Charlotte Islands it has since appeared in restricted infestations over most of the Coastal area both on Vancouver Island and on the mainland. No outbreak of major importance has yet occurred nor has any serious degree of defoliation resulted.

The spruce aphid is generally restricted to the eastern side of Moresby Island in the Queen Charlotte Islands. A very unhealthy condition of the affected spruce has resulted from continued aphid attack and, despite its present limited range, considerable speculation is advanced by foresters over the possibility of this aphid being responsible for the large quantity of dead Sitka spruce scattered throughout the mature stands.

The Douglas-fir tussock moth has caused widespread damage throughout a large section of the southern portion of central British Columbia during 1947-48. As in the case of the hemlock looper and of the black headed budworm, this infestation was preceded by extensive outbreaks south of the International Border. The infestations have been restricted to areas within the Interior dry belt, where great damage has occurred among Douglas fir. No estimate of the total area or volume of affected timber is possible due to the isolation and size of the areas concerned.

The Sitka-spruce weevil has become a major problem in the growing of Sitka spruce on the British Columbia coast. So greatly has it damaged spruce plantations that reforestation of spruce has been abandoned.

Bark beetles remain the major perennial forest insect problem in central British Columbia where the mountain pine beetle, *Dentroctonus monticolae* Hopk., the western pine beetle, *D. brevicomis* Lec., and the Douglas-fir beetle, *D. pseudotsugae* Hopk., have caused severe depletion of the stands. In recent years the Douglas-fir beetle has been particularly active in the Interior, while the mountain pine beetle has appeared in fairly large outbreaks in the white pine stands of the Coast.

The following insects have appeared in outbreak proportions during the past ten years without causing any extensive killing of forest stands: European larch sawfly, forest tent caterpillar, the fall webworm, *Hyphantria textor* Harris., and hemlock sawfly.

Research

Since the termination of World War II, it has been possible to put into effect long-deferred plans for the expansion and development of forest entomology in British Columbia. Progress has been made in assembling a nucleus of young scientists, now under training, as a foundation for a service which will be enlarged and improved. This expansion is essential for the comprehensive treatment of the many complicated insect problems important to the salvage and continuity of the timber resources of the territory. At present, two small laboratories, Victoria for the coastal work and Vernon for the interior region, constitute the forest insect organization in the province and these operate under unified direction. Excellent co-operation is received from the British Columbia Forest Service and the work is closely coordinated with requirements of this provincial service and the forest industry in relation to insect outbreaks and other urgent entomological problems. From this nucleus it is planned to develop, at the Coast, a basic research centre for forest entomology which will incorporate facilities for coping with fundamental problems in forest insect fluctuations in the British Columbia region. Some of the major research projects at present under intensive investigation in British Columbia are discussed in the ensuing paragraphs.

The forest insect survey is in the process of being developed into a long term ecological study. Fourteen insect rangers have been added to the staff in the Province. A 61-foot boat "J. M. Swaine" equipped as a field laboratory operates over the coastal areas of British Columbia. The future plan entails two survey centres for the identification and rearing of living insect material, one in the Interior and one on the Coast. Added to this will be summer ranger stations in various forest districts to serve as field headquarters for rangers located in particular regions of the province. Although the foundation for this project is established much work and planning is still required before the ultimate objective of a sound insect survey materializes.

A study of the deterioration of hemlock looper defoliated timber constitutes one of the most pressing problems in the field of utilization and salvage. This investigation, in progress since 1946, aims at the determination of factors contributing to losses in timber values from both the entomological and pathological aspects; and at supplying information that can be used by the Province and the industry in appraising the status of affected timber on occasions of future outbreaks. It covers such aspects as marginal defoliation beyond which recovery is problematical, the relation of site, density, composition and age class to resulting mortality, the development of rot and the attack of secondary insects, the urgency for salvage and time available for practical salvage operations.

Studies on the bionomics of the hemlock looper, black headed budworm and oak looper have progressed during the past ten years, with emphasis on the incidence of disease, particularly virus, as a control agent. In addition to the study of disease and other factors of natural control, the work has developed techniques and procedures applicable to field studies in insect pathology.

The quantitative measurement of populations of defoliating insects through frass collections appears to offer much in the determination of population trends. This project, which has been in progress for two years, was initiated on the premise that there is a constant relationship between the portion of the leaf giving rise to growth and that voided as frass. This study is yet too young for definite conclusions nor has it been conducted with more than one species but it opens an important avenue for further study in the quantitative analysis of defoliating insects.

Forest nursery and plantation insect studies have been initiated in British Columbia since the war's end. Reforestation has gained so much impetus that such studies have become increasingly important. Three nurseries have at present an annual production of 10 million seedlings, with a fourth nursery of 350 acres in the process of development. Current research is aimed at supplying annually knowledge of the status of destructive and potentially destructive insects in both the nursery and plantation areas.

Studies on the control of defoliators through aeroplane spraying have been undertaken on two occasions. The first in 1946 employed a twin motor land-based plane, the second in 1948 a helicopter. On each occasion approximately 12 thousand acres were sprayed. Although these treatments were entirely satisfactory as control measures over the areas sprayed, it was evident that the many obstacles inherent to the Province restrict this form of control. In application it appears little more than an emergency measure to protect localized areas of high value where conditions of the region permit this type of flying.

Investigations into the bionomics of ambrosia beetles have been conducted over a wide variety of conditions and progress made in an understanding of the nature of behaviour as influenced by seasonal and various ecological factors. Repellents have thus far proved unsatisfactory, the only satisfactory control being cutting and utilizing during beetle-free months. Kiln drying of infested lumber is a satisfactory treatment in the immediate termination of an active population. Mill studies are planned for the determination of degrade resulting from these insects according to various periods of cutting and storage of logs.

3. Fruit Insects and Mites of the Interior

By J. Marshall, Dominion Fruit Insect Laboratory, Summerland, B.C.

The fruit industry of the British Columbia interior produces from 10 to 13 million packages per year, of which approximately 99 per cent are tree fruits. The industry is carried on in an area roughly 400 miles east to west and 160 miles north to south. The fruit growing districts vary in elevation from 1100 to 2200 feet above sea level; precipitation varies from about 9 inches per annum in the semi-arid South Okanagan Valley to nearly 30 inches in the Kootenay Valley. Maximum temperature is about 105° F. in the South Okanagan and 95° F. in the North Okanagan and Kootenay Valleys; minimum temperature ranges from about 5 degrees below zero to 30 degrees below zero. The whole area is divided into narrow valleys by high mountain ranges.

Such wide climatic variations coupled with the geographic isolation of the various fruit districts produce an assortment of entomological and phytopathological problems that require the annual preparation of four distinct spray charts. The more important orchard insects and mites of the Interior are discussed in the following numbered paragraphs.

1. The European red mite, *Metatetranychus ulmi* (Koch.) attacks chiefly apple, pear, prune, plum and peach. Since the advent of DDT it has replaced the codling moth, *Carpocapsa pomonella* (L.), as the most serious pest of the British Columbia tree fruits industry. Apparently there are several reasons for this change in status, the most important, no doubt, being the injurious effects of DDT on certain predators of the red mite. This mite is controlled by the standard dormant spray mixture of lime sulphur-heavy dormant oil (220 S.S.U. Vis. at 100° F.) followed by summer application of 2, 4-dinitro-6-cyclohexylphenol 2 oz. per 100 gal. or its monoethanolamine salt. There are indications that greater stress will shortly be placed on the use of a "pink" application for this pest. Within a few years parathion will probably supplant the dinitro compound for summer applications.

2. The Pacific mite, *Tetranychus pacificus* McG., is, so far, confined to the Okanagan and Similkameen Valleys and attacks chiefly apple, prune, plum and cherry. It is potentially a more serious pest in the arid or semi-arid areas, as under favourable conditions i.e. hot, dry weather, it multiplies more rapidly than the European red mite. As a rule, however, seasonal conditions in British Columbia do not suit it as well as the European species. Control is accomplished by foliage sprays of the same acaricides as used against European red mite; dormant applications are of little value.

3. The pear leaf blister mite, *Eriophes pyri* (Pgst.), is a pest of pear and certain varieties of apple. It is controlled by the standard lime sulphur-heavy dormant oil spray.

4. The San José scale, *Aspidiotus perniciosus* Comst., is fairly widespread in the interior fruit belt. It attacks all types of tree fruits and is controlled by lime sulphur-dormant oil spray as mentioned under European red mite. A close relative, the European fruit scale, *A. ostreaeformis* Curt., is noteworthy in that it may be confused with San José scale by fruit inspectors. Otherwise it is not a serious pest.

5. The oyster shell scale, *Lepidosaphes ulmi* (L.), chiefly a pest of apples in the more northern fruit sections of the province, is only periodically of importance. It is now controlled chemically by application of DDT a week to ten days after petal fall.

6. The tarnished plant bug, *Lygus oblineatus* (Say), can generally be expected to cause serious though scattered injury. Damage consists of "catfacing" of peaches and "blasting" of apple and pear flower buds. For many years this insect defied all attempts at chemical control; recently, however, good results have been secured from an application of DDT just after petal fall. A high speed sprayer seems to be particularly useful for this purpose since, as it moves forward, it blankets a large area with concentrated spray fog and presumably gives effective contact of this active bug.

7. The western peach tree borer, *Sanninoidea exitiosa graefi* (Hy. Edw.), is injurious to peach and prune in scattered orchards through-

out the area. A simple, rapid and fairly effective control measure is the application of DDT spray to the tree trunks early in July and again in August. That procedure will probably be recommended in 1949.

8. The peach twig borer, *Anarsia lineatella* Zell., is not a consistently injurious insect in British Columbia. Nevertheless, its attacks are serious enough to earn it distinction as the worst pest of peach. Investigations are under way to determine if it may be feasible to introduce parasites for its control. In the meantime, several means of chemical control have recently been under trial and may find favour with the growers. These include a delayed dormant spray of parathion or DDT or a "pink" spray of DDT. The standard control, so far, has been a "pink" application of lime sulphur.

9. The pear thrips, *Taeniothrips inconsequens* (Uzel.), is restricted to a portion of the Kelowna district. Until it was found to be very susceptible to a dormant application of DDT this was a serious pest.

10. The pear psylla, *Psylla pyricola* Foerst., appeared in British Columbia in 1942 and is now generally distributed in the Okanagan and Similkameen valleys. During years of greater than average rainfall it has proved to be a pest of importance. Control is effected by a very early spring application of heavy dormant oil or by summer applications of nicotine sulphate-summer oil, rotenone-summer oil, or benzene hexachloride-summer oil. The last is the most effective but can only be used early in the season because of its tendency to taint the fruits. Chlorinated camphene and parathion have been distinctly promising as foliage applications in orchard trials against the pear psylla and will probably supplant the other spray mixtures.

11. The rosy apple aphid, *Anuraphis roseus* Baker, is sporadically abundant, particularly in orchards that are densely planted. The most effective control measure for this species has been a dormant application of oil-dinitrocresol or oil-dinitrocyclohexylphenol. Parathion will probably prove to be more effective than either of these spray mixtures.

12. The apple aphid, *Aphis pomi* Deg., year by year is not so destructive as the rosy apple aphid. It is controlled, where necessary, by summer applications of nicotine sulphate-soap or rotenone-summer oil. As with other aphids, there are indications that the recommended material for control of this species will shortly be parathion.

13. The woolly apple aphid, *Eriosoma lanigerum* (Hausm.), was a serious pest of the British Columbia apple industry some twenty years ago. Its feeding, particularly where on callus tissue, produced conditions favourable for the development of the fungus causing perennial canker, a disease that threatened to eliminate such varieties as Jonathan and Newton and Pippin. Introduction of the parasite *Aphelinus mali* (Hald.) effectively checked the aphid and reduced perennial canker to minor importance. Recent use of DDT for codling moth has, in some instances, appeared to have given the woolly aphid a new lease of life by reason of its high toxicity to *A. mali*. Consequently chemical control is again a matter for concern. The summer sprays currently recommended are nicotine sulphate-oil and benzene hexachloride-oil and as with pear psylla control, the latter may be used only in early applications. Parathion will probably find wide use against this pest as soon as it is considered safe to recommend it.

14. The black cherry aphid, *Myzus cerasi* (F.), a pest that has been causing increasing concern in recent years, is controlled by dormant oil-dinitrocresol or dormant oil-dinitrocyclohexylphenol. Application of this type of material has become general among cherry growers.

15. The mealy plum aphid, *Hyalopterus arundinis* (F.), a generally distributed and troublesome pest of prunes and plums, is controlled by the same spray mixtures as the rosy apple aphid.

16. Treehoppers, *Ceresa bubalus* (F.) and *C. basalis* Walk., sometimes cause concern to the owners of young fruit trees because of the injury they inflict on immature wood with their saw-like ovipositors. Recent work in the Okanagan Valley has shown that an application of DDT just as the eggs begin to hatch in spring followed by a second treatment when oviposition begins in the fall, gives a considerable measure of control.

17. The apple mealybug, *Phenacoccus aceris* Sign., as recently as five years ago was a formidable pest attacking all types of orchard trees in the Kootenay Valley where it first appeared in 1927. A localized infestation exists in the Okanagan Valley. Introduction of the parasite *Allotropa utilis* Mues. was begun in 1937 and proved so successful that chemical control of the mealybug is now generally unnecessary.

4. FRUIT, ORNAMENTAL AND GREENHOUSE INSECTS IN THE COASTAL AREA

By H. ANDISON, Dominion Fruit Insect Laboratory, Victoria, B.C.

The main agricultural areas in the Coastal section of British Columbia are the lower Fraser Valley, which is largely alluvial soil that extends some 80 miles inland along the Fraser River, and the south eastern portion of Vancouver Island, a narrow strip about 160 miles long. All of this was originally a dense coniferous forest, of which only the more level land, to an elevation of not more than 400 feet above sea level, has been put under cultivation.

In these agricultural areas the average annual rainfall varies from as high as 65 inches in the lower Fraser to below 30 inches on Southern Vancouver Island. The precipitation falls chiefly during the winter months with prolonged dry spells frequently occurring during the summer. Some sections in this mild climate receive over 2100 hours of sunshine annually which makes them ideal locations for the rapidly expanding greenhouse and nursery industry. The climate is also very favourable for small fruits, nuts, bulbs, ornamentals, and, to a lesser degree, tree fruits.

Fruit Insects

(a) *Small fruits.*

Small fruits such as strawberries, raspberries, loganberries, blackberries, currants and gooseberries have shown a steady annual increase in commercial quantities produced. Of the 5600 acres planted to small-fruits, approximately 92 per cent is located in the lower Fraser Valley and Vancouver Island districts of the Province. Their annual total value to the producer is now over 4,100,000 dollars.

1. The western ten-lined June Beetle, *Polyphylla perversa* Cys., is a most important pest of strawberries, loganberries and tree fruit seedlings. On Vancouver Island it has caused some growers to discontinue growing strawberries on light and medium soils where as high as 70 per cent of the plants have been destroyed annually by the white grub.

During the past two years the Victoria laboratory has obtained encouraging results in field experiments to control the larvae in the soil. Benzene hexachloride and ethylene dibromide at 1 lb. gamma and 1·6 gallons respectively per acre, have shown sufficient promise to warrant their recommendation to growers for test purposes.

2. Root Weevils. Both the strawberry root weevil, *Brachyrhinus ovatus* (L.), and the black vine weevil, *B. sulcatus* (F.), are major pests of strawberry, raspberry and blueberry plantings. Both these species are parthenogenetic and can, in a short time, become sufficiently numerous to cause considerable damage. During the past 15 years commercial growers have obtained excellent control of these insects by two applications of a poisoned apple pulp bait. The bait is applied to poison the adults, which emerge during mid-April and during the second week in June.

3. The western raspberry fruitworm, *Byturus bakeri* Barber, has caused considerable concern to the loganberry and raspberry industries in the lower Fraser Valley, where as high as 30 per cent of the fruit in some plantings has been infested by the larvae. The standard recommendation of rotenone materials, applied during blossom time to control the larvae, proved to be costly and unsatisfactory. During the past two years the Victoria laboratory has found that two applications of DDT, applied prior to blossom time to control the adults, have given excellent control. During 1948 loganberry and raspberry growers who followed our recommendations harvested an excellent crop free from *Byturus* larvae.

4. The leafhopper, *Typhlocyba tenerrima* H. S., has caused considerable damage to the foliage of loganberry, blackberry and raspberry on Vancouver Island. Reported as a serious economic pest in Europe, it was first noticed in the Victoria district during 1947 which appears to be a new record for Canada. Preliminary studies in this area indicate that it has three generations per year and is readily controlled by one application of either DDT or parathion during mid-May before the nymphs develop wings.

5. The raspberry root borer, *Bembecia marginata* (Harr.), has been gradually increasing and causing damage to raspberry and loganberry plantings on Vancouver Island and the lower mainland. No satisfactory chemical control is known at the present time.

6. The currant fruitfly, *Epochra canadensis* Loew, was the most important limiting factor in the growing of currants and gooseberries in this area. Now that DDT is being used in two applications *i.e.* immediately after petal fall and again 10 days later, this insect is no longer a serious pest.

7. The redberry mite, *Aceria essigi* (Hasson), is prevalent on blackberry and raspberry fruits in both sections at the Coast. It is readily controlled by two applications of lime sulphur—as a dormant spray 1-10 and when the fruiting arms are 4 to 6 inches long, 1-40.

8. Throughout the entire coastal area, *Tetranychus* mites have been causing damage to strawberry and raspberry foliage, particularly after harvest time. Sprays and dusts containing sulphur have given only partial control and the dinitrophenol materials have caused injury to the foliage.

9. The Puget Sound wireworm, *Ctenicera aeripennis aeripennis* (Kby.), is fairly common and troublesome on land planted to strawberries in the coastal areas, especially if the land has been previously in sod. It is not generally found in the low-lying areas when water drainage in the winter is poor. Excellent results have been obtained with the same chemicals that are suggested for the control of June beetles. Where wireworm damage to strawberry plants is observed after planting, a side dressing of benzene hexachloride 5 per cent dust, immediately cultivated in, has given quick, effective control.

(b) *Tree fruits.*

The tree fruit production in the two coastal sections amounts to approximately 1500 carloads annually, which have a value of about 500,000 dollars.

1. The European apple sawfly, *Hoplocampa testudinea* (Klug), first recorded here during 1940, has become a major pest of apples grown on Vancouver Island. It does not occur anywhere else in Canada. Satisfactory control has been obtained by using nicotine sulphate in combination with oil as a calyx spray.

2. The apple and thorn skeletonizer, *Anthophila pariana* (Clerck), has continued to increase and cause extensive damage to the foliage of apple and cherry trees at the Coast in unsprayed orchards. Two applications of DDT, as a calyx spray and a cover spray during the first week of July, have satisfactorily controlled this species.

3. The codling moth, *Carpocapsa pomonella* (L.), and lesser appleworm, *Grapholitha prunivora* (Walsh), have both been destructive to the fruits of apples and pears in the coastal areas for many years. Now that the DDT 3-spray programme has been generally accepted by the growers, the control of these two insects is no longer a major problem.

4. The western tent caterpillar, *Malacosoma pluviale* (Dyar), usually held in check by native parasites, continues to be a problem every seven to ten years causing damage to the foliage of apple, cherry, plum and various ornamentals. It is readily controlled by DDT.

5. The pear thrips, *Taeniothrips inconsequens* (Uzel), was a major pest of pears and plums in both sections of the coastal area until 1945, when it was found to be very easily controlled by a dormant application of DDT.

6. The pear leaf blister mite, *Eriophyes pyri* (Pgst.), is fairly widespread as a pest of pear and some varieties of apple. It is readily controlled by a dormant application of lime sulphur in combination with oil applied once every three years.

7. The black cherry aphis, *Myzus cerasi* (F.), is sporadically abundant. Effective control has been obtained with a dormant application of either oil-dinitrocresol or oil-dinitrocyclohexylphenol.

8. The apple mealybug, *Phenacoccus aceris* Sign., was recently (1944) discovered causing damage to apples in the Vancouver Island area. The application of dormant oil-lime sulphur or oil-dinitrocyclohexylphenol sprays has controlled it. Introduction into this area of the parasite *Allotropa utilis* Mues., which has proved so successful in the Kootenay Valley, was begun July, 1948.

9. The cherry fruitfly, *Rhagoletis cingulata* (Loew), is troublesome on the cherry fruits, particularly the Olivet variety. The standard control recommendations of two sprays containing rotenone, commencing when the Royal Anne's show red, have proven to be satisfactory.

10. The lecanium scale, *Eulecanium coryli* (L.), attacks chiefly apple, pear, plum, prune and peach in the coastal areas. An application of dormant oil-lime sulphur or a post-harvest spray of summer oil emulsion in combination with nicotine sulphate will control this insect.

(c) *Filbert nuts.*

The filbert nut industry is a relatively new one which has rapidly increased its plantings to 315 acres. As the majority of these commercial plantings are less than 10 years old, no reliable yield data are available.

1. The filbert bud mite, *Phytoptus avellanae* Nal., widely distributed throughout the coastal area, damages the catkins, flowers and leaf buds of filberts. A delayed dormant spray of lime sulphur readily controls this pest.

2. The aphid *Myzocallis coryli* (Goetz.) is commonly found feeding on the leaves which it covers with a sticky honey-dew. Two or three applications of nicotine sulphate and soap thoroughly applied will control it.

Insects Attacking Ornamentals

No detailed figures are available concerning the acreage and value of ornamental and nursery stock grown in British Columbia. The majority of the nurseries that grow ornamental plants are located at the Coast.

The bulb industry in British Columbia consists of 560 acres representing a total annual value of approximately 335,000 dollars. Of this total acreage, 492 or 90 per cent is located on Vancouver Island and lower mainland.

1. The holly leaf miner, *Phytomyza ilicis* Curtis, is a pest wherever holly is grown. It is very susceptible to a single petal-fall application of DDT.

2. The soft scale, *Coccus hesperidum* L., is mainly a pest of holly. There appears to be a sudden increase in the abundance of this species following the general use of DDT for leaf miner control by commercial growers.

3. The narcissus bulb fly, *Lampetia equestris* (F.), has continued to increase in spite of the hot water treatment generally practised by commercial growers. In many cases this increase may be explained by the fact that no agitation apparatus is installed in the home-made hot water tanks. Consequently, the proper temperature of 110° F. is not maintained for 1 hour as required to kill the larva in the narcissus

bulb. Commercial control of the fly may be effected by a bulb storage treatment with methyl bromide or by two applications of a summer oil emulsion in the field during the oviposition period.

4. Root weevils. The black vine weevil and the clay coloured weevil, *Brachyrhinus singularis* (L.), are major pests of primula, rose, rhododendron, holly and many other ornamentals in both coastal areas. The application of poisoned apple pulp baits to kill the adults before they lay their eggs is a satisfactory control method.

5. The gladiolus thrips, *Taeniothrips simplex* (Mor.), commonly occurs wherever gladoli are grown. DDT has given fairly good control of this species in commercial plantings.

6. Wireworms have caused extensive damage to gladioli in the lower mainland area. On light well-drained soils, the Puget Sound wireworm, *Ctenicera aeripennis aeripennis* (Kby.), is the chief pest species; and on the low-lying poorly-drained land *Ctenicera lobata* (Esch.) and *Agriotes* sp. are destructive. Promising control has been obtained by using ethylene dibromide or benzene hexachloride prior to planting the corms.

Greenhouse Insects

The greenhouse industry in British Columbia is an important one comprising an area of 5,066,950 sq. ft. (114 acres) under glass which is operated by 552 growers. Approximately 93 per cent of this area is located in the Vancouver Island and lower mainland districts. Because of the suitable climate, over 50 per cent of the industry is situated in close proximity to Victoria, on Vancouver Island.

1. The two-spotted spider mite, *Tetranychus bimaculatus* Harvey, is a common and most serious pest of greenhouse roses, carnations and cucumbers. This species has in the past been a most difficult one to control. The new and promising acaricides such as parathion and tetraethyl pyrophosphate as sprays and in aerosols are proving to be most satisfactory.

2. Thrips. The greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), is widely distributed as a pest of roses, cyclamen, carnations. The chrysanthemum thrips, *Thrips nigropilosus* Uzel, is commonly found attacking chrysanthemums. The long-winged thrips, *Scirtothrips longipennis* Bagn., causes damage to begonias and cyclamen. All three are readily controlled by DDT.

3. The chrysanthemum leaf miner, *Phytomyza atricornis* Mg. (= *chrysanthemi* Kow.), is common wherever chrysanthemums and cineraria are grown.

4. The chrysanthemum aphid, *Macrosiphoniella sanborni* (Gill.), is chiefly a pest of chrysanthemums and one which has always to be considered in the spray programme.

5. The green peach aphid, *Myzus persicae* (Sulz), is the most common greenhouse insect attacking a great variety of plants such as carnations, snapdragons, chrysanthemums, cineraria, primula and begonias.

6. Mealybugs, *Phenacoccus* sp., rank among the most troublesome pests with which the florists have to contend. They attack coleus, begonias, fuschia, ferns, palms, rose and geranium.

7. The orange tortrix, *Argyrotaenia citrana* (Fern), was first observed in the coastal greenhouses during 1931 and has since become well established as a pest of rose, cyclamen, asparagus fern, geranium, chrysanthemum and cypress seedlings.

8. The greenhouse whitefly, *Trialeurodes vaporariorum* (Westw.), has very general feeding habits and is chiefly troublesome on tomato, cucumber, pelargonium, primula and fuschia. Growers who have taken advantage of the Dominion Parasite Laboratory service of supplying the parasite *Encarsia formosa* Gahan have reported satisfactory results from biological control.

9. Scale insects. The soft scale and the fern scale, *Pinnaspis aspidistrae* (Sign.), cause damage to ferns, gardenias, oleander and palms.

10. The root knot nematode, *Heterodera marioni* Goodey, is generally distributed causing economic losses chiefly to tomato. Most commercial growers practise steam sterilization for its control.

11. The cyclamen mite, *Tarsonemus pallidus* Banks, is a widely distributed and most destructive pest of cyclamen, begonias and chrysanthemum.

12. The tarnished plant bug, *Lygus oblineatus* (Say), generally causes serious injury to chrysanthemums, the damage consisting of "blasting" of flower buds. Recently good control has been obtained with DDT.

13. The black vine weevil is especially destructive to cyclamen, primula and begonia.

5. Field Crop Insects of the Interior

By E. R. Buckell, Dominion Field Crop Insect Laboratory, Kamloops, B.C.

Field crops of the Interior include such diverse types as potatoes and other vegetables, all of high value per acre, grown on irrigated land in the southern valleys; forage and cereal crops in the developing central section; the wide wheat fields of the Peace River Block, a north-west extension of the Prairie Region; and native grasses of the extensive grazing land on the central plateaux. A few of the pests, notably grasshoppers, have on occasion affected all of these. Most of them, however, are at present somewhat restricted in range, owing in part to the isolation of agricultural districts. In some instances, e.g. wireworms, the problem recurs in different areas but with a change of species.

1. Grasshoppers periodically cause a great deal of damage in British Columbia. The range lands of the province suffer the most, but during some outbreaks the cultivated crops in the valleys are also attacked. Outbreaks occur at fairly regular intervals of eight to ten years but may vary greatly in intensity. During some of the outbreaks the whole of the southern half of the province may be affected, while at other times only certain limited and highly favourable areas are involved. Some of the cattlemen's associations maintain well organized control zones and conduct annual control work to lessen the chance of serious outbreaks, and, where *Camnula pellucida* (Scudder) is the dominant species, and their egg-beds are known, good control has been maintained.

The species responsible for most of the outbreaks is *Camnula pellucida* (Scudder), the clear-winged grasshopper. Its activity is confined mainly to the high open cattle ranges where it has been known to cause almost complete destruction of the grasses. It is mainly a grass feeder. Cultivated crops, other than hay and grain, are seldom attacked. Its habit of congregating in small restricted areas of alkaline soil to deposit its eggs would make its control a simple matter were it not for the rough, often inaccessible, nature of the country it inhabits. Overgrazing of cattle ranges may greatly extend its breeding grounds as it seldom deposits its eggs in well grassed pastures.

The lesser migratory grasshopper, *Melanoplus mexicanus mexicanus* (Saussure), has only once to our knowledge occurred in outbreak numbers over the whole of the interior of the Province. During the outbreak it infested not only the lower southern valleys—its natural habitat—but also occurred in great numbers over the highest grasslands of the cattle ranges, usually exclusively a *C. pellucida* habitat. It is an exceedingly destructive species and very few plants, wild or cultivated, escape its attention. It does not concentrate its egg pods in definite egg-beds and has proved a very difficult species to control.

While there are a number of species which may contribute to range depletion during outbreak years none can compare in importance to these two. Sometimes *M. bivittatus* (Say) occurs in injurious numbers in small isolated locations in the interior, and *M. femur-rubrum* (DeGeer) may do likewise in the coastal regions.

2. Potato flea beetles have become increasingly important, particularly since the potato tuber flea beetle, *Epitrix tuberis* Gent., became established in the southern interior of the Province. This species is a serious menace to potato growing, as the larvae attack the tubers causing shallow holes and surface channels necessitating deep peeling and rendering the tubers more susceptible to disease. The western potato flea beetle, *Epitrix subcrinita* (Lec.), may cause serious leaf injury but does not attack the tubers.

3. The cabbage flea beetle, *Phyllotreta albionica* Lec., is a troublesome pest of cruciferous plants such as cabbage, turnips and radishes, being particularly destructive to the seedling plants.

4. Wireworms are one of the most persistently annoying pests of vegetables throughout the Interior and, like most soil insects, are hard to control. They are particularly destructive to seedling onions and a single wireworm may destroy many of the young plants in a row. Potatoes are frequently attacked and rendered unfit for market by the tunnelling of these insects, and cabbage transplants are subject to heavy damage. The chief of these problems occurs in irrigated land, particularly in soils of lighter texture, where the Pacific Coast wireworm, *Limonius canus* Lec., is the chief species, aided to some extent by the western field wireworm, *L. infuscatus* Mots. In the Peace River block, the wireworm, *Ctenicera aeripennis* (Kby.), is a major problem of wheat growing.

5. White grubs are a common pest in the Interior, and difficult to control. These are the large ten-lined June beetle, *Polyphylla perversa* Csy., and a smaller brown species *Phyllophaga anxia* (Lec.). The grubs are capable of gnawing off the roots of young fruit trees and raspberry canes and are a serious pest of strawberries. Both species

are particularly destructive to potatoes, eating large irregular holes in the tubers. It needs only a few white grubs in a home garden to cause severe damage to vegetables and flowers.

6. Cutworms are present in sufficient numbers to cause damage every season, although the amount of injury may vary greatly from year to year. The black army cutworm, *Actebia fennica* (Tausch.), may be rare for long periods and then suddenly appear in immense numbers over limited areas where they are particularly destructive to alfalfa in early spring. Some are single, and some double brooded, and the winter may be passed as eggs, immature larvae or adults. In some species the larvae feed exclusively at, or slightly below ground level, while others, such as *Spaelotis clandestina* (Harr.), are climbing cutworms and will cause damage to young fruit trees and grape vines by eating out the buds. Cutworm injury is particularly noticeable to cabbage and tomato plants when first set out in the field. Among the species that have recently been collected and reared from infested fields may be mentioned the red-backed cutworm, *Euxoa ochrogaster* (Guen.), the striped cutworm, *Euxoa tessellata* (Harr.), the dark-sided cutworm, *Euxoa messoria* (Harr.), the variegated cutworm, *Peridroma margaritosa* Haw. and *Euxoa flavicollis* Sm.

7. The cabbage maggot, *Hylemya brassicae* (Bouché), is the most serious pest of cabbages and cauliflowers in British Columbia. The fly lays its eggs close to the stem of the young plants and the maggots attack the roots and not only destroy the fibrous roots, but bore into the tap root where winding tunnels are formed. Severely injured plants will wilt and die. Radishes are also attacked by the maggots and rendered unfit for food.

8. The onion maggot, *Hylemya antiqua* (Meig.), is more prevalent in wet seasons and after several consecutive wet summers may become so numerous as to make onion growing very unprofitable unless thorough control measures are taken. In years of heavy infestation as high as 90 per cent of the crop may be killed. While most of the damage occurs to the young plants the later generations will also enter mature onions just before harvesting causing them to rot very badly in storage.

9. Onion thrips, *Thrips tabaci* Lind., has, in some seasons, considerably cut down the yield of onions, the acreage of which has increased considerably in recent years. When abundant the bulbs are distorted and small and seed crops may be a complete loss. When onion fields are heavily infested the leaves turn a whitish or silvery colour and soon wilt and die. Although onions are the favourite food plant, other vegetables may be attacked and quite serious damage to young cucumber plants has been observed. The onion thrip is particularly abundant in dry hot weather and seldom causes noticeable damage to cool, damp seasons.

10. The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), now established throughout almost the entire United States and Canada, entered the south eastern corner of British Columbia in 1911. A series of high mountain ranges and lake-filled valleys proved a formidable barrier, and it was not until 1943 that the beetle made its appearance elsewhere in the Interior. An annual control campaign undertaken by the Provincial Department of Agriculture and the advent of better insecticides, such as DDT, have kept the potato beetle

at a low level and to date the actual loss has been small. It remains, however, as a source of annoyance and a potential threat to the potato industry of the Province, and careful control measures will have to be maintained to prevent its further spread or even to prevent its increase to serious proportions in the areas it now occupies.

11. Blister beetles occasionally are abundant and destructive to certain field crops and to home gardens in the dry Interior. As the larvae of the economic species feed on grasshopper eggs, their occurrence coincides with local grasshopper outbreaks. They are distinctly gregarious and will collect together on a few plants, or a portion of a field, moving on to fresh plants as their food supply becomes exhausted. They are ravenous feeders and can cause much damage in a short time. The most important species is *Epicauta oregona* Horn. This beetle is particularly fond of potatoes, field tomatoes and alfalfa as well as some garden vegetables and flowers. Among weeds its favourite food plant is lamb's quarter, *Chenopodium album* Linn. Three other species, *Lytta sphaericollis* Say, *E. pruinosa* Lec. and *E. puncticollis* (Mann.) are of less importance, but during grasshopper outbreaks may sometimes be seen in great numbers feeding on snowberry, *Symphoricarpus racemosa* Michx., on the open cattle ranges and they may attack alfalfa and caragana hedges.

6. FIELD CROP INSECTS IN THE COASTAL AREA

By R. GLENDENNING and K. M. KING, Dominion Field Crop Insect Laboratories, Agassiz and Victoria, B.C.

The chief form of agriculture in this area is dairying, but potatoes, hops, peas, vegetables and some seed crops are also grown extensively in addition to forage crops for the cattle.

Nearly all the agricultural insect pests found in this area are introduced species, usually from Europe, the climate and agriculture being largely similar to those of the western part of that continent. The following are the chief European introductions:

Asparagus beetle	*Crioceris asparagi* (L.)
Cabbage aphid	*Brevicoryne brassicae* (L.)
Cabbage root maggot	*Hylemya brassicae* (Bouché)
Cabbage seedpod weevil	*Ceutorhynchus assimilis* (Payk.)
Carrot rust fly	*Psila rosae* (F.)
English grain aphid	*Macrosiphum granarium* (Kby.)
European earwig	*Forficula auricularia* L.
Hessian fly	*Mayetiola destructor* (Say)
Hop aphid	*Phorodon humuli* (Schr.)
Imported cabbageworm	*Pieris rapae* (L.)
Pea aphid	*Macrosiphum pisi* (Kltb.)
Pea leaf weevil	*Sitona lineata* (L.)
Pea moth	*Laspeyresia nigricana* (Steph.)
Pea weevil	*Bruchus pisorum* (L.)
Tarnished plant bug	*Lygus oblineatus* (Say)
Wheat midge	*Sitodiplosis mosellana* (Géhin)
Grey garden slug	*Arion circumscriptus* (Hohn)
Brown slug	*Deroceras agrestis* (Linn.)
Great slug of Europe	*Limax maximus* L.
Slug	*Arion ater* (L.)

All these pests are without their natural parasites, with the possible exception of the cabbage seedpod weevil, and as a result they often assume epidemic proportions and require artificial controls. Efforts have been made, and are continuing, to introduce their respective parasites. Considerable success has been achieved in the case of the pea moth and to a lesser extent with the European earwig.

Nothing definite is known of the mode of introduction of any of these pests, but the fact that their first appearance was near the seaboard would indicate that they were brought by ship. Some undoubtedly migrated up the coastal plain from the older settlements in Oregon and California. Few if any appear to have crossed the Rocky Mountains.

The number of important insect pests native to the coastal region, or which have spread by natural means from adjacent areas on this continent, is very small, doubtless due in large part to the character of the original vegetation. These are:

Western potato flea beetle	*Epitrix subcrinita* (Lec.)
Tuber flea beetle	*Epitrix tuberis* Cent.
Sugar-beet root aphid	*Pemphigus betae* Doane
Cabbage flea beetle	*Phyllotreta albionica* Lec.
Pacific Coast wireworm	*Limonius canus* Lec.
Puget Sound wireworm	*Ctenicera aeripennis aeripennis* (Kby.)

Cereal Crop Insects

Except for oats, grain acreage is quite small in the coastal regions, and insect pests of these crops do not assume the serious proportions that they do on the Prairies. The English grain aphid and the apple grain aphid, *Rhopalosiphum prunifoliae* (Fitch), occur at times, but are usually controlled by parasites, predators and weather. The wheat midge causes damage quite regularly, but cultural control through early seeding avoids heavy infestation. The hessian fly occurs on Vancouver Island, but is troublesome only when non-resistant varieties are grown. On the lower mainland it is absent probably due to greater rainfall and winter cold. The corn earworm, *Heliothis armigera* (Hbn.), appears in some years but does not persist.

Clover Insects

Red clover is an important crop in the predominantly dairying area of the lower mainland and Vancouver Island. However the luxuriant growth masks the effect of the general feeders on this crop, as well as the temporary injury caused by the pea leaf weevil to clover and vetch. Cutworms in epidemic numbers are very rare, while slug feeding is usually inappreciable. The clover leaf midge, *Dasyneura trifolii* (Loew.), has been recorded but its work is seldom noticeable. The clover root curculio, *Sitona hispidula* (F.), has been present many years but apparently has seldom found conditions sufficiently to its liking to become a pest.

Where red clover is grown for seed both the seed midge, *D. leguminicola* (Lint.), and the seed chalcid, *Bruchophagus gibbus* (Boh.), appear, but only cause serious loss to the seed crop in areas continuously devoted to seed production. Cultural control by means of seasonally timed clipping is effective in keeping them to negligible numbers.

Alfalfa thrives only in a very few areas on the coast and no insects of importance hinder its growth.

Hop Insects

The lower Fraser Valley is the most important hop-growing area in Canada, some three to four thousand acres being devoted to this crop. Three pests of importance are prevalent—the hop aphid, the hop flea beetle, *Psylliodes punctulata* Melsh., and the common red spider, *Tetranychus telarius* L.

The nicotine shortage has necessitated changes in the control of the hop aphid and no substitute of equal value to nicotine dust has been found to date. Tetraethyl-pyrophosphate is being tested with some initial success.

The hop flea beetle is readily controlled by derris, nicotine dust or DDT, but grease banding is still practised in some yards.

The red spider has been a serious pest since the early days of hop growing in the province, being most abundant in hot dry summers and on sandy soils. Its control has been difficult, and prior to the advent of adequate spraying machinery this pest ruined many small growers. Sulphur and lime-sulphur sprays, and DN and sulphur dusts have been used, while latterly tetraethyl pyrophosphate has shown promise.

In recent years the oblique-banded leaf roller, *Archips rosaceana* (Harr.), has taken to feeding on hops but its actual status as a hop pest is still in doubt.

Potato Insects

Potatoes are an important crop on the lower mainland of British Columbia and on Vancouver Island. The tuber flea beetle is of major importance because of the larval feeding on the tubers and difficulty of control; it is a recent immigrant from Colorado and has not yet spread to all of the coastal potato growing district. The western potato flea beetle, which is abundant generally, also requires control measures, though the foliage feeding by the adults of both species is largely overcome by the luxuriant growth at the Coast. In studies of the tuber flea beetle under way in the lower Fraser Valley, and more recently in the Interior, high mortality of adults is obtained by means of derris, DDT and benzene hexachloride, but complete elimination of the scarring of the tubers from larval feeding has not yet been achieved.

The growing of certified seed potatoes for export has become, in recent years, an important and lucrative operation. In view of this, the occurrence of the aphid species *Macrosiphum solanifolii* (Ashm.) and *Myzus persicae* (Sulz.) is now causing concern as probable vectors of disease. These aphid species are moderately abundant in the coastal areas, but become much less so further inland and at greater elevations, probably because of lower winter temperatures. The control of these aphids is unsatisfactory at present: nicotine is in short supply, the effectiveness of DDT has not been exactly determined, and the use of benzene hexachloride is restricted by its tainting of the potato tubers.

The control of all potato insects in the coastal regions is complicated by the necessity of frequent applications of fungicides to control late blight, *Phytophthora infestans* (Mont.) de Bary, so that any insecticides to be economical must be compatible with copper dusts or sprays.

Pea Insects

The cultivation of field peas for canning, drying or seed is an important industry and affords ample breeding facilities for three pests, the pea aphid, the pea moth and the pea weevil.

The pea aphid is regularly abundant in the littoral areas, the milder winters there allowing overwintering in the viviparous stage on clover; further inland overwintering is usually only possible in the egg stage. Control is still in an unsatisfactory state. Airplane dusting of various materials is being tried in an effort to avoid the damage done to the vines by ground machines, and the factor of DDT residue on the vines when used as silage is still undetermined.

About 1934 the pea moth appeared in the coastal area of British Columbia, and in a few years resulted in the practical elimination of dry and seed pea growing. It was found that cultivation of the soil harbouring last season's cocoons greatly reduced moth emergence if the soil disturbance was timed to coincide with the pupation period. However, this pest has been almost eliminated in recent years by the establishment of three of its natural parasites from Europe. Recent studies have shown that a DDT emulsion is an effective control in the egg and young larval stages and has possibilities for both field and garden peas.

The pea weevil is seldom a pest in the coastal areas, and while it has been recorded for many years on the lower mainland, it rarely overwinters successfully in the field in this area of heavy rainfall. The pea leaf weevil, introduced in recent years, has become more abundant on peas grown for canning, where the scalloping of the leaflets causes concern. On southern Vancouver Island it seriously attacks peas, beans, and sweet peas as they come through the ground. It is readily controlled with DDT.

Vegetable Insects

Of importance in this area are the imported cabbage worm, the cabbage root maggot, the cabbage aphid, the cabbage flea beetle, and the carrot rust fly. The onion maggot, *Hylemya antiqua* (Mg.), is more serious in the Interior than at the Coast.

The imported cabbage worm is an abundant and persistent annual pest of all brassica crops on the lower Mainland, though readily controlled by DDT dusts or derris dusts; on Vancouver Island, however, it is troublesome only occasionally, as in 1948. Mercury solutions and dusts have been standard treatments against the cabbage root maggot, but improved and cheaper control is indicated by the use of benzene hexachloride, and stem treatment with DDT. However, so far no practical and economical control has been found for this pest on field turnips and consequently few turnips are grown in this area. The cabbage flea beetle is a serious pest of all brassicas in the seedling stage in the spring as well as later when the new generation adults emerge in August, especially after a hot summer. Derris, nicotine or DDT dusts afford an effective control, especially DDT with its greater lasting qualities. The cabbage aphis remains difficult to control, and strong nicotine dusts are the most effective remedy at present.

The carrot rust fly appeared in British Columbia in 1936 and for many years severe losses were caused to seedling carrots, especially by the first generation larvae. Three generations occur annually, one more than in England. Although naphthalene or calomel dust gave fair control, recent experiments have shown that benzene hexachloride dust gives almost 100 per cent control without tainting the carrots. This has been an important advance in control, and has already been widely and successfully used by growers.

The asparagus beetle appeared at the Coast in 1934, and has since spread wherever this crop is grown, though the acreage involved is small.

Vegetable Seed Crop Insects

During World War II vegetable seed production became important, and two pests caused serious losses to the infant industry. The cabbage seedpod weevil, spreading from various cruciferous weeds, soon built up to epidemic numbers. A brief study of its biology failed to produce a practical control. However after a year or two of abundance, two species of European parasites *Trichomalus fasciatus* Thoms. and *Bracon* sp.(?) became abundant, apparently having been imported with their hosts. On Vancouver Island, this weevil is still a major hazard to turnip and cabbage seed production.

The parsnip webworm, *Depressaria heracleana* (L.), also appeared when parsnip seed growing became common during the war. Severe losses occurred, with up to 75 per cent of the seed being destroyed. Various materials were tried to kill the larvae in the webs, but with little success until it was found that cryolite dust blown into the webs was rapidly and peculiarly toxic to this species.

In recent years the production of sugar beet seed has been undertaken to a limited extent in the milder coastal lands. The tarnished plant bug, through its "stinging" habit of feeding on the ovules, has impaired the germination of the seed produced. This species is widespread and a general feeder, breeding chiefly in red clover fields. When these become dry or are cut for hay the bugs migrate to other crops. A 3 per cent DDT dust has been found to be an effective control.

General Feeders

Cutworms are relatively scarce in the coastal areas. However, occasional epidemics have been recorded of the alfalfa looper, *Autographa californica* (Speyer), the variegated cutworm, *Peridroma margaritosa* (Haw.) and the black cutworm, *Agrotis ypsilon* (Rott.). On Vancouver Island, *Euxoa excellens* (Grt.), is often destructive in limited areas.

Wireworms are of considerable importance in restricted areas, affecting tobacco, potatoes, cabbage and other vegetables, as well as gladiolus and young strawberry plants. The Pacific Coast wireworm is the chief species, occurring chiefly in bottom lands of light and medium textures. The western field wireworm, *Limonius infuscatus* Mots., is troublesome in the better drained soils of light texture. The Puget Sound wireworm is often important following sod, chiefly on upland soils. Two species recently found in the Fraser River delta, also apparently originating in grassland but at present of minor importance, are: *Ctenicera lobata* (Esch.), of which the only previous record of economic importance, according to M. C. Lane, was in Alaska; and a species of *Agriotes* having "eye-spotted" larvae, possibly an introduction from Europe.

The western ten-lined June beetle, *Polyphylla perversa* Csy., often causes serious loss to potatoes, brassicas, and other vegetable crops on Vancouver Island.

Grasshopper plagues do not occur in the coastal areas. Very rarely the red-legged grasshopper, *Melanoplus femur-rubrum* (Deg.), has appeared in numbers, but the luxuriant growth is hardly affected by their feeding.

The European earwig first appeared in 1916, and for many years was a serious pest in Coast cities. It eventually spread to rural areas where its depredations in ears of corn were appreciable. In recent years it has become less abundant and appears to have reached static numbers, and although present in both urban and rural areas, is seldom reported as a pest of consequence. The tachinid parasite *Digonochaeta setipennis* Meigh, was bred and liberated about 1926, and apparently has become established. However, it is doubtful if parasitism by this fly accounts wholly for the reduction of earwig population that has taken place. Probably it has been one amongst other unknown factors that have been co-operatively responsible for the decrease.

Three species of slugs have become established and widespread on the lower mainland. These are: the grey garden slug, which is also troublesome on Vancouver Island, the brown slug, and the great slug of Europe. A native species, the reticulated slug, *Prophysaon andersoni* (Cooper), is also a pest, frequently climbing plants in order to feed. In 1945 the species *Arion ater* (L.) was found near the port of New Westminster. This is the only record for Canada. In wet seasons serious damage is often done to field and truck crops, especially young corn, potatoes, lettuce and seedling truck crops. The first two species mentioned are the chief pests. The use of metaldehyde baits and the application of dilute soluble copper dusts afford protection, but epidemics under field conditions are primarily related to poor mechanical structure of the soil.

The millipede, *Diplionlus hortensis* (Wood), appears to be increasing in abundance on southern Vancouver Island, often causing damage to garden seed in the spring and to potato and dahlia tubers in the autumn. It is found chiefly in heavier textured soils that are wet in winter.

7. INSECTS, TICKS AND MITES ATTACKING LIVESTOCK AND MAN

By J. D. GREGSON, Dominion Livestock Insect Laboratory,
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Cattle ranching is one of the main industries in the Interior Dry Belt of British Columbia. In this region of rolling rangelands are located some 175,000 head of beef animals. These are owned largely by ranching companies which maintain separate herds of about three to ten thousand head. These animals are pastured on large areas of leaseland, many ranges extending over a million acres. Once they are turned out from their winter feeding quarters, few of the animals are seen or handled until roundup time in the fall.

Scattered among the cattle ranges are smaller sheep pastures. Here groups of several thousand sheep graze for a month or more on the spring growth, after which they are gradually moved to high altitude summer camps situated above timberline. This trek may cover a distance of one or two hundred miles. In the fall they are brought down for shipping, or wintering at a home ranch. There are approximately 45,000 head of sheep in the province.

Dairy cattle, located mostly in the damper valleys of the Fraser and Thompson rivers, while numbering only some 30,000 head, form a third important group of livestock in British Columbia. Domestic animals of lesser economic importance, though present in fair numbers, include horses, swine, poultry and fur bearers.

Ticks

Of the twenty species of ticks recorded for British Columbia four are of economic significance to livestock and man. These are the paralysis tick, *Dermacentor andersoni* Stiles, the winter tick, *D. albipictus* (Pack.), the Pacific Coast tick, *Ixodes pacificus* Cooley, and the soft tick, *Ornithodoros hermsi* Wheeler, Herms and Meyer. Other ticks of lesser economic importance include *I. texanus* Banks, a parasite of mustelid fur bearing animals; *Haemaphysalis cinnabarina* Koch, and *H. leporis palustris* Packard, both vectors of tularaemia in Interior game birds and rabbits; *I. auritulus* Neumann, a common pest of coast game birds, and *Otobius megnini* (Duges), a potential pest of livestock, recorded to date only from the ears of British Columbia mountain sheep and deer.

1. The paralysis tick, the most serious of these, owes its importance to the fact that a single female tick, through feeding, may paralyse its host. Although recovery occurs shortly after the tick is removed, failure to detach the parasite often results in the death of the individual due to respiratory failure. Sheep and cattle paralysed by this tick on separate occasions vary in number from individual cases to outbreaks involving hundreds of head. As many as a hundred head have been lost during a single outbreak. There is also an additional loss in all animals that recover due to labour in deticking infested animals and to depreciation in their condition. If the stock is held back from spring pastures until the tick season is over, there is also the cost and effect of substituting hay for green grass. In humans, paralysis usually results from the feeding of a single tick. Among some hundred and fifty cases, about a dozen have been fatal, these having resulted from a failure to locate the causative agent in time to effect recovery.

The paralysis tick is confined to the Interior and is more commonly associated with the "dry belt" district. Its characteristic ecological habitat overlaps the distribution of rangeland bunchgrass (*Agropyron* spp.) though it is by no means as general in extent and frequently is restricted to relatively small areas comprising a few square miles. In such localities adult activity is often confined to gullies containing briar and underbrush where undoubtedly the early stages of the tick find the necessary small rodent hosts. While not numerous, the adults are present in sufficient numbers for a grazing animal to pick up a dozen or so within a day, an ample number to produce a case of paralysis. At certain talus slopes at the bases of cliffs adults of this tick may be collected by the usual tick dragging method at the rate of hundreds per hour.

Adult tick activity in British Columbia commences as early as February, reaches a peak in mid-April, and ends about mid-May, depending to some extent upon the location and exposure of the site. Tick activity appears to cease without regard to temperature and humidity conditions and aestivation lasts until the following spring.

2. The winter tick is strictly an animal parasite and is of Dominion-wide distribution. While not causing paralysis, it has been proven to be capable of transmitting corynebacterial infections, a disease commonly associated with deer and sheep, and quite possibly plays a part in maintaining this disease in portions of this Province. In addition, infestations of this tick on horses and moose are frequently so severe as to kill the animals, or failing this to lower their condition to a state bordering death. While domestic animals can be treated for this pest, it is virtually impossible to protect game animals from its attacks. Unlike the preceding species whose first two stages feed on rodents, this is a single host tick. The larvae congregate in the autumn in clusters on grass and twigs in deer haunts. When opportunity offers, they transfer to their host, on which they remain throughout the winter, passing successively through larval, nymphal and adult stages. As with the paralysis tick, this species mates while engorging, the gravid females then dropping to the ground for oviposition.

3. The Pacific Coast tick is chiefly of medical importance, though it is an important parasite of dogs and cats, has on occasion bothered sheep, and undoubtedly undermines the health of Coast deer and other wild life. Its distribution is decidedly spotty and local, coinciding largely with that of the Madrona tree (*Arbutus menziesii* Pursh) and snowbrush (*Ceanothus sanguineus* Pursh) in the coastal region of British Columbia. Since some of its habitats occur in heavily populated residential areas such as portions of West Vancouver and Victoria, it will be seen that it is a pest of considerable significance to human welfare. While not having been incriminated with the transmission of any disease, it nevertheless is capable of producing a severe toxaemia and slow healing ulcers at the site of attachment, and because of its long hypostome is a difficult tick to remove when once attached. Its two early stages infest lizards, and since these and warm-blooded adult hosts such as dogs and cats abound in the infested areas, the eradication of this pest presents a complicated problem.

4. Of recent significance to public health is the discovery in British Columbia of *Ornithodoros hermsi* Wheeler, Herms, and Meyer. This argasid tick has on many occasions been proven a vector of the relapsing fever spirochete in the United States. It readily bites humans and has transmitted this disease to them in at least six western states. Several cases of human relapsing fever have occurred in British Columbia, but until 1948 all attempts to demonstrate a suspected argasid vector had failed. In 1948, a series of specimens were taken from a residence in the Okanagan Valley, where the ticks were migrating from a bluebird nest and biting humans. Although these specimens were free from spirochete infection and were not collected from an area where the disease has been reported, the fact is now established that a relapsing fever vector is present in this Province.

Warbles and Bots

1. The common cattle grub, *Hypoderma lineatum* (DeVill), and the northern cattle grub, *H. bovis* (Deg.), are present throughout the

cattle ranching districts of British Columbia. The former is the more abundant and the earlier of the two, the peak of grub emergence occurring at Kamloops in mid-March. By the end of May, when the resulting flies emerge, the grubs of the second species are ready to drop. While the latter fly is the more vigorous in its attacks, individual infestations seldom exceed a dozen grubs per animal and *H. lineatum*, which may occur in numbers up to a hundred and fifty per cow, is undoubtedly the more serious pest. Combined, these species cause serious losses to the beef and dairy industry due to poor conditioning of cattle and resulting depreciation of meat, milk and leather yields. Control of these pests, while practised on a large scale with the aid of power sprayers using derris suspensions, is far from complete, and well organized campaigns to eliminate warble infestations have yet to be put into effect in this Province.

2. Of importance to native caribou is the Caribou warble fly, *Oedemagena tarandi* (L.). Though occurring more abundantly in the Arctic regions, larvae of this species do occur in mountain caribou nearly as far south as Kamloops, British Columbia. Infestations by this insect have been known to exceed a thousand grubs per animal.

3. Three species of bot flies affect horses in British Columbia: the nose bot fly, *Gasterophilus haemorrhoidalis* (L.), the throat bot fly, *G. nasalis* (L.), and the horse bot fly, *G. intestinalis* (Deg.). Though no survey has been made in this province to ascertain the severity of infestations, it is assumed from casual examinations that there is a need for a much more concerted bot fly control effort.

4. A variety of other bots occur in British Columbia, attacking livestock, game animals and rodents. These include the sheep bot fly, *Oestrus ovis* L., caribou nostril and throat flies, *Cephenomyia* spp., and rodent warbles, Cuterebridae. The latter commonly infest packrats, mice and chipmunks. Poultry, grouse and mink may possibly also be affected by species of this group.

Other Pests

1. Although mosquitoes are among the worst bloodsucking flies that affect livestock in many parts of Canada, their importance to range animals in British Columbia is overshadowed by their importance to humans in most Interior urban and rural areas, as well as in the Coastal flood plains. As a result, well organized mosquito control campaigns have been established by some dozen major communities who have now reduced this pest below nuisance proportions. Success in this connection has been all the more apparent during the last year or two when DDT has played a prominent part in control operations. Applied at the rate of about a tenth of a pound per acre from aircraft or from ground equipment, aqueous and oil concentrates of this chemical have replaced the older method of applications of straight fuel oil.

Over forty species of mosquitoes are involved in the main breeding areas in British Columbia. The latter consist, for the greater part, of pools in rangeland depressions created by melting snow; lake and river floodlands, which are residual ponds left by receding floodwater; and permanent or temporary ponds created largely by irrigation water. *Anopheles* mosquitoes occur in this province, but climatic conditions are not suitable for the survival of the malarial parasite and this disease consequently does not constitute a problem. On the other hand, it is more or less an accepted fact that mosquitoes are implicated in the transmission of encephalomyelitis, a disease that is receiving considerable attention in medical and veterinary fields.

2. Blackflies in British Columbia are a greater pest to humans than to livestock. This is due to their abundance in many of the mountain parks of the Province where they definitely affect the tourist industry. However, in spite of the variety of species produced by the different types of streams, only a few species such as *Simulium venustum* Gay are of economic significance. Recent discoveries of the amazing lethal effect of small amounts of DDT (as little as one part per twenty million of water) in running water has rendered control of blackfly larvae in streams a simple matter, and it is anticipated that, with careful regard to fish and beneficial aquatic life, blackflies will soon become a problem of the past.

3. Horseflies are second in importance among the bloodsucking insects affecting livestock. In British Columbia two common genera, *Tabanus* and *Chrysops,* are particularly abundant around most rangeland marshes where they seriously torment horses and cattle that are unable to secure suitable shelter. Control of these pests, which are relatively resistant to DDT, is difficult, though it has been noted that many are parasitized, and interesting observations have been made along these lines.

4. Hornflies merit more attention from ranchers, as their presence in large numbers on cattle materially affects the condition of stock. Control by DDT sprays should be possible if it were practical to treat range animals.

5. Houseflies and stableflies are pests of considerable significance around farmyards and piggeries. Fortunately, with the advent of DDT these carriers of diseases can now be controlled very easily with a few applications of spray to farm buildings each summer.

6. Blowflies or screwworms normally breed in carrion, but occasionally will "strike" living animals immediately after shearing or dehorning when suitable conditions prevail. Maggot infestations or myiasis, however, are few and can be prevented by carefully treating all wounds with disinfectants.

7. Cattle lice are of the most important of the sucking and biting parasites, though surveys have shown that British Columbia is less troubled by these pests than are any of the other provinces. An examination of 837 beef and 275 dairy cattle showed the respective percentages of infested animals to be 6·4 and 11·6 as compared to average Dominion figures of 18·6 and 32·0. It has been apparent that of the infested animals, beef cattle are more likely to become severely attacked than are dairy stock, and it is not uncommon for one or two individuals in a herd of otherwise healthy stock to exhibit extreme cases of lousiness. That such infestations are readily apparent renders culling out and treatment of these animals a simple matter.

Four species occur across the Dominion, namely *Haematopinus eurysternus* (Nitz.), *Bovicola bovis* (L.), *Linognathus vituli* (L.), and *Solenopotes capillatus* End. The first two species are the most abundant, *H. eurysternus* being most prevalent on beef cattle and *B. bovis* on dairy herds. *B. bovis* is a biting insect, and dairy cattle are often only lightly infested. In such cases the infestations are only potentially serious in that they form a reservoir that will provide a source of heavy breeding as soon as suitable conditions arise.

8. Hog, horse, and fowl lice are all common in this Province, but, as in the case of cattle lice, are readily controlled by modern insecticidal dusts.

9. The bedbug, *Cimex lectularius* L., is not a serious pest in British Columbia, reports of infestations being received occasionally from owners of rooming houses and other buildings of transient occupancy. A high school was reported as being infested with *Oeciacus vicarius* Horv. This parasite of swallows is present in large numbers wherever these birds nest and will temporarily transfer its attention to humans.

10. The sheep-tick, *Melophagus ovinus* (L.), is one of the most prevalent of the sheep parasites. The presence of a small number of these keds is not a source of much worry to sheep, but under favourable conditions their steady increase may result in a serious infestation in a flock. This is true during the winter, when sheep are penned or herded closely together, and at this season, due to lowered resistance, the effects of the keds are most apparent. Although rather easy to control, little effort along this line has been made by ranchers in this Province.

11. The chicken mite, *Dermanyssus gallinae* (Deg.), is without question the worst pest affecting poultry in Canada, and is so generally distributed that almost every poultryman is familiar with its appearance. Unless exceptionally well kept, the majority of poultry houses exhibit infestations of this nocturnal parasite, which, if unchecked, will rapidly build up to an extent that seriously affects the health and productivity of the chickens concerned.

12. Other mite pests of livestock include the mange and scab mites. Fortunately, infestations of these various parasites of cattle, horses, sheep, hogs and poultry are relatively scarce.

13. Fleas are not a serious problem in British Columbia. Occasional infestations occur in houses that shelter dogs and cats. Infestations of the human flea are rare. Sometimes infestations occur in sawdust storage where this fuel is used by householders. In such cases breeding may continue for some time in the absence of dogs or cats.

14. *Xenopsylla cheopis* (Roths.) occurs on rats in coastal regions. This flea is one of the chief vectors of bubonic plague in the Old World.

8. INSECT PESTS OF STORED PRODUCTS AND THE HOUSEHOLD

Assembled[1] by K. M. KING

Most of the insect pests in this group, in British Columbia as elsewhere, are cosmopolitan species. Nevertheless the particular species involved in this Province, or their relative abundance, may be somewhat characteristic.

The spider beetle, *Ptinus ocellus* Brown (= *tectus* auct.), is the most important and widespread pest of cereal materials in the

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[1] From notes specially supplied by H. E. Gray, Chief, Stored Product Insect Investigations, Ottawa, Ont., and by J. D. Gregson; and from data by British Columbia authors in The Canadian Insect Pest Review and elsewhere.

Province. This is especially true in the Coastal area, where this species is common and difficult to control in houses, as well as in warehouses, and there have been some very serious outbreaks in stored fishmeal. In the Interior, where spider beetles are also of considerable importance, there is a blending of the species found on the Prairies, such as the hairy spider beetle, *P. villiger* (Reit.), and the white-marked spider beetle, *P. fur* L., with *P. ocellus* from the Coast.

Feed is an important item on the Coast. The meal snout moth, *Pyralis farinalis* (L.), is often abundant, and the yellow mealworm, *Tenebrio molitor* L., is common around many ground-feed stocks, especially those that are slightly out of condition. The seed moth or brown house moth, *Hofmannophila pseudospretella* Staint., has been taken only on the Coast where it occurs in large numbers in some feed warehouses.

The two pests usually most common in small mills are the confused flour beetle, *Tribolium confusum* Duval, and the Mediterranean flour moth, *Ephestia kuehniella* Zell. With them is the cadelle, *Tenebriodes mauritanicus* (L.). Some of the carpet beetles such as the black carpet beetle, *Attagenus piceus* (Oliv.), are particularly damaging at times to bolting silk, and often feed on used sacks. The Indian meal moth, *Plodia interpunctella* (Hbn.), is frequently encountered in imported rice. Several of these pests, as well as the saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.), cause trouble in packaged goods and household stocks.

Of these pests of whole grain, the granary weevil, *Sitophilus granarius* (L.), the rice weevil, S. *oryza* (L.), and the saw-toothed grain beetle occur commonly, and no doubt are present in numbers in farmers' bins. The yellow meal worm is also very common around whole grain stocks, even though only a slight effort is needed to keep it well in check there.

The bean weevil, *Acanthoscelides obtestus* (Say), is commonly found in British Columbia. The pea weevil, *Bruchus pisorum* L., mentioned in the preceding papers, is also troublesome in stored peas.

The carpet beetle, *Anthrenus scrophulariae* (L.), and the varied carpet beetle, *A. verbasci* (L.), are important pests of the household, especially on the Coast. Clothes moths are common, perhaps more so in the Interior, though a very destructive infestation by the case-making clothes moth, *Tinea pellionella* L., was encountered at Victoria in a large shipment of Persian rugs. The firebrat, *Thermobia domestica* (Pack.), appears to be on the increase at Victoria.

Structural timber is not, on the whole, subject to any extensive injury by insects. However, on the Coast, powder post beetles, *Lyctus* spp., have in a number of instances heavily attacked house timbers, occasionally necessitating the replacement of cellar beams. Destructive attack by the European death watch beetle, *Anobium punctatatum* (Deg.), has also been recorded recently in the Lower Fraser Valley, involving timbers in houses as well as antique furniture. Termites are not a really dangerous pest here, but the native species, *Zootermopsis angusticollis* Hagen, common in decaying stumps and roots ,on the Coast, is capable of causing much injury to timber placed in direct contact with the soil, though easily controlled by proper construction. Another termite, *Reticulitermes hesperus* Banks, has recently been found in flooring at Kamloops.

The Pharaoh ant, *Monomorium pharaonis* (L.), has become quite troublesome at Victoria, and is difficult to control. Other ant species also occasion numerous inquiries in the Coastal area, but are a rather minor problem in the Interior.

Cockroaches, chiefly the German cockroach, *Blattella germanica* (L.), frequently occur in cafes, hotels and public institutions, though now much more easily and effectively kept down with the newer insecticides.

Among pests, chiefly invaders, which cause inquiry or annoyance, and sometimes damage, in or around homes in British Columbia, may be listed: wasps, often very abundant in the late summer; European earwig, *Forficula auricularia* L., chiefly on the Coast, but now also spread to a few Interior localities; sowbugs, mainly on the Coast; pseudoscorpions in the Interior; and wolf spiders on the Coast.

RECENT DEVELOPMENTS IN FOREST ENTOMOLOGY IN CANADA

By J. J. de Gryse, Forest Insect Investigations, Ottawa

[*Abstract*]

The climate of Canada favours the development of periodic widespread outbreaks of forest insects endowed with catastrophic powers of destruction. Dealing with such outbreaks calls for large-scale investigations and remedial measures. An elaborate system of annual surveys has been devised. The results of these surveys provide the basic material for fundamental laboratory studies in ecology, epidemiology, physiology, genetics, and parasitology of destructive species. These results, in turn, are integrated with exact field observations made in as many strategic locations as the problems and available facilities warrant. Studies in control measures are based principally on forest management and on biological control. The possibilities of chemical and other artificial control measures are studied with a view to supplement the above in special emergencies and as palliatives. The over-all organization, the operation and some results obtained to date are described in detail. Projected developments are discussed.

THE ORIENTAL FRUITFLY (*DACUS DORSALIS* HENDEL) IN HAWAII

By D. T. Fullaway, Board of Agriculture and Forestry, Honolulu

The Oriental fruitfly (*Dacus dorsalis* Hendel), a recent immigrant to the Hawaiian Islands, has proved to be a major fruit pest, far exceeding in destructiveness the Mediterranean fruitfly (*Ceratitis capitata* Wiedemann), which species it has almost completely displaced in the common edible fruits of Honolulu and its vicinity.

This species was first recognized in May 10th, 1946, when adult flies were bred from mangoes collected at Alexander Street, Honolulu. The fly had evidently been present for some time without recognition. Once the identity had been established previous captures were reported as follows: a female *D. dorsalis* was found amongst 2,500 fruitflies reared or collected between April and July 1945 by O. C. McBride, in charge of the U.S. Bureau of Entomology Fruitfly

Laboratory in Honolulu; W. C. Look, Plant Inspector at Hilo, Hawaii, reported that he had reared the fly from fruits of waiawi (*Psidium cattleianum*) collected on Hawaii, November 18, 1945; Willis W. Wirth, entomologist with the U.S. Public Health Service in Hawaii, reported having collected the fly in Hawaii in December 1945. From these records *D. dorsalis* appears to have been introduced into the Territory in the latter part of 1944 or the early part of 1945. Circumstantial evidence points to marine forces returning from Saipan as the means by which the species gained access to these islands. In Saipan the fly is said by Esaki (*Proc. Sixth Pacific Science Congress,* 1940, 4: 413)[1] to be very injurious to citrus and other fruits.

Entomologists working in Hawaii believe that the fly became established first on the island of Hawaii, whence it spread to other islands of the Hawaiian group. It was identified on Kona and Kohala in May 1946, on Maui in June, on Kauai in October and on Molokai in November, on Lanai in February 1947 and on Niihau in August. Traps were set out on Molokai in July 1946 and no flies were captured. These dates do not necessarily represent the times of introduction, but the times at which *D. dorsalis* was positively identified on a particular island.

The fly increased rapidly. The utility of Ceylon citronella oil as a lure for male flies was learned early and traps put out to gather distribution data revealed an astonishing abundance everywhere, e.g. May '46 Kohala 174 flies trapped in 10 minutes; Aug. 1, 1947, Manoa 250 in 5 hours; Makiki, 400 in 19 hours; Kewalo, 800 in 48 hours.

ECONOMIC IMPORTANCE

The Oriental fruitfly in Hawaii displays very little selectivity or choice of host fruits in which to lay its eggs and the host list after two years is exceedingly long, above 80 already, which is more than can be recorded for the Mediterranean fruitfly in 38 years of study. The economic importance of the fly is posited in its destructiveness to the commoner marketable fruits, such as the mango, avocado, banana, papaya and fig, and its menace to fruit growers in California and the American states of the Gulf Coast where citrus fruits, a favoured host in Formosa, are the big item in fruit production. Fortunately it does not normally[2] attack pineapple, the one fruit of really great economic importance to Hawaii (1947 production close to 61 million dollars). Export of fresh fruit, even pineapples and bananas, which previous to 1940 were shipped to the west coast of America in considerable volume is now prohibited by federal quarantines unless the fruit is treated in such a way that all developmental stages of the fly (eggs, larvae, pupae) are killed – an expensive procedure seriously limiting its application.

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[1] This report records *D. dorsalis* on Okinawa (Ryukyu Islands) also. This year (1948) it was discovered in Guam.

[2] Owing to the recent discovery of an infestation in an overripe pineapple and the subsequent rearing of a number of *D. dorsalis* from this fruit, pineapple must now be considered a host fruit, although infestation is believed to be rare, resulting from attraction of ovipositing females to fermenting fruitlets and breaking down of digestive enzymes in the fruit (which normally vitiate fruitfly eggs and larvae) during the fermentation process. There is a report of rearing *D. dorsalis* from pineapple under similar circumstances in Formosa. Vide Koidsumi, K. & Shibata, K., 1935. Notes on the Autecology of Some Fruitflies 11. On the Mango Fly *Chaetodacus ferrugineus* var. *dorsalis* Hendel, *J. Soc. Trop. Agr.*, 7, No. 4: 370-78, Taihoku, Dec. 1935.

Besides spoilage in edible fruit caused by injury when the fly deposits its eggs, and by the worms developing therefrom feeding on the pulp, injury has also been observed to blooms of certain orchids, gingers, etc., which emit fragrant odours attracting the male flies of *D. dorsalis*. The injury is in the nature of a spotting which results from tissue destruction beneath droplets of regurgitated liquid food dried too rapidly by the sun, and affects adversely the saleability of the flowers.

It is stated by Bezzi (*Phil. Jn. Sci.*, 15 (5), Nov. 1919) that *D. dorsalis*, originally described from Formosa, has a wide range in the Oriental region, occurring naturally from India to the Philippines, and from Java to Formosa, but this has not been verified and further study is believed necessary to elucidate the rich Trypetid fauna of these regions. I believe there is no doubt about identifying the fly in Hawaii with the one described from Formosa as *D. dorsalis*. Reference has been made to its similarity to *Dacus cucurbitae* but it has a very superficial resemblance to that fly. It is well characterized in the following description by Hendel (Hans Sauter's Formosa-Ausbeute Genus *Dacus* Suppl. Ent. No. 1, p. 18, Berlin, fig.):

[The greater part of Hendel's detailed description of the adult is omitted.—Ed.]

"Body 6-8 mms. Wings 5-7 mms. 119 males and females ex Formosa, Koshun, Sept. Remarks: *Dacus ferrugineus* Fabricius is distinguished according to Wiedemann's description by the rust-yellow, also unspotted front. The dorsum of the thorax is rust reddish brown and not a decided black. Froggatt mentions, however, in his Fruit-flies, 1910, p. 13, the great variability of this species in the colour, from red-brown to black. It is regrettable that he says nothing whatsoever as to whether the front is spotted or not. His illustration of the wing (Pl. V Fig. 8) agrees with the Formosan examples. Very characteristic of our species are the two shining spots on the 5th tergite. It is very probable that what Froggatt and others have described as *ferrugineus* is partly this species (*dorsalis*)."

Shiraki in his work on the fruit insects of Formosa also describes the adult, egg, larva and pupa and gives a short account of the life-history, as follows:

[Shiraki's descriptions of adult, egg, larva and pupa omitted.—Ed.]

"Life-history. Females appear from July to September. Fruit most severely damaged is the mango. Distributed all over Formosa but not discovered in highland forest area. Lay their eggs 2-30 in one cluster. Mainly about 10. Larval stage 2 days to 3 weeks. Stay in the fruit 17-35 days and then go into the ground and pupate. Pupal stage 6 to 27 days. The adult prefers to feed on fruit juice and starts laying eggs after mature."

Koidsumi and Shibata have studied the life-history and habits of the fly in Formosa and the following abstract of their "Notes on the Autecology of the Mango-fly *Chaetodacus ferrugineus* var. *dorsalis* Hendel" taken from the *Review of Applied Ent.*, Ser. A, 24: 275 (1936) furnishes data similar to that obtained in Hawaiian studies:

> *Dacus dorsalis* Hend. is a very serious pest in Formosa, where it has several generations a year and infests a wide range of fruits.

The adults are more active than those of *D. cucurbitae* Coq. and a larger space is required for breeding them.

They emerge before noon, and are most active at 25-30° C. (77-86° F.), becoming dormant below 20° C. (68° F.).

They live about a week when given water only, and over a month when fed on honey, but do not oviposit. They live much longer and lay eggs when fed on banana or other fruits.

Oviposition begins 20 days after emergence in summer, 25-60 days in autumn, and 100 in winter, when flies were fed on orange juice.

Females that were about to oviposit drove away others from the fruits.

They lay fewer eggs in a fruit than *D. cucurbitae*, only 20-30 larvae being usually found even in a large one, as compared with 200-300 of the latter species. A single egg hole generally contains 5-10 eggs. The number of eggs laid by one female is usually about 500 and sometimes 1000.

Even citrus fruits that are strongly acid (pH.2·2-2·7) are sometimes attacked, and larvae mature in them.

Flies in captivity laid eggs in ripened papaya, bruised pineapple, banana, pear, apple and persimmon, and larvae matured in all except the last two, though these are not usually attacked in the field. Apple is not grown in Formosa. Captive flies also laid eggs in lemon, but the eggs or newly hatched larvae died.

In the northern part of Formosa, the flies are dormant in winter though they emerge from the pupae, and the eggs and larvae do not develop.

In Hawaii, the activities of the fly have been studied by Miss Mabel Chong and others, and the following data accumulated. In cage rearings (summer months) 16 days was required for development in banana from deposition of egg to emergence of adult fly; 23 days in papaya.

DURATION OF DIFFERENT STAGES IN DEVELOPMENT

	Days (Spring Months)				Average
Egg	2	2	3	2	2
Larva	9	25*	19	12	16
Pupa	8	9	10	9	9

* Wide variation in duration of larval stage believed due to environmental conditions, as fruits vary greatly in texture and moisture content of pulp.

Length of life of adult fly is unpredictable but is generally longer when properly fed.[3] The pre-oviposition period ranges from 8 to 16 days. Flies are believed to mate at night or in the early morning.[4] Chester Keck has recorded (*Proc. Haw. Ent. Soc.*, 13 (2): 219) mating one hour after darkness 22 days after emergence of flies.

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[3] In an experiment begun Aug. 15th with 50 female and 50 male flies of *Dacus dorsalis* reared from papaya, flies which had emerged on the preceding day and during the course of the experiment fed on papaya juice diluted with water and sweetened with honey, there was gradual decline in numbers from the very beginning but highest mortality occurred in the 3rd week of the experiment; the last female succumbed on Oct. 18th, the last male Nov. 7th. This fly lived through 86 days.

It is generally believed that infertile eggs do not hatch. Mating in confinement is difficult to secure. In most of our life-history studies, experiments began with gravid females captured whilst seeking to oviposit on ripe fruits. Working with such flies, it was observed that even ripe fruits are carefully explored for soft spots where the ovipositor can be inserted readily. Advantage is taken also of bruises, cracks and very thin areas of the skin.[5]

Percentage Emergence of D. dorsalis in 14 Fruits
September 1947

		No. Fruits	No. Pupae	No. Adults	% Emerged
Artocarpus communis	Breadfruit	2	121	60	49
Averrhoa carambola	Star-fruit	10	43	26	60
Carica papaya	Papaya	4	383	382	99
Carissa grandiflora	Natal plum	10	31	26	84
Citrus sp.	Lemon	10	27	18	67
Eugenia jambos	Rose Apple	10	192	150	77
Ficus carica	Fig	25	407	357	88
Musa sapientum	Apple banana	20	48	31	65
Opuntia megacantha	Cactus fruit	10	19	7	37
Persea americana	Avocado	10	465	322	69
Psidium guajava	Guava	20	520	326	63
Psidium cattleianum	Strawberry guava	25	155	91	59
Spondias dulcis	Wi apple	55	90	47	52
Terminalia catappa	Kamani	20	610	330	56

Data on oviposition showed no regularity or consistency indicating a behaviour pattern. Some flies hold their eggs for several days and then oviposit; others expel their eggs immediately on being placed with suitable fruit, placing as many as 300 or more in one cavity. Many cavities contained less than 10 eggs.

The eggs are glistening white, about 1 mm. long, elongate elliptical with narrower rounded ends.

The larvae on hatching are about 1 mm. long but increase in size gradually to about 8 mms. when full grown. They are elongate, widest at posterior end where width is about one-seventh of length and posterior spiracles are prominent, narrowing gradually to pointed anterior end, where the chitinous mandibles or mouth-hooks and anterior spiracles are located.

The puparia are elliptical in general shape, 4-5 mm. long, colour light to dark testaceous. Anal spiracles conspicuous on posterior end.

The fly is active the year round, although development is retarded somewhat by the lower temperature of the winter months.[6]

D. dorsalis displays very little selectivity in host-relationship, and in this differs from other *Dacus* species with which we are familiar. The host-list which follows includes most of the common fruits of Hawaii exclusive of cucurbitaceous fruits.

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[4] It was found on checking the sex of several thousand flies that males and females maintained about even numbers.

[5] Another experiment was planned to check the percentage of flies which succeed in passing through the developmental stages, on basis of host-fruit in which development took place.

[6] While the fly is commonest below the 2,000 ft. level, it has frequently been found infesting fruit above that level. Mr. Davis, of the National Park Service, reared it from fruits of *Solanum pseudocapsicum* collected at Kipuka Ki, Hawaii, 4,000-4,500 ft. The fly itself has been seen active at 5,500 ft. elevation in Kilauea National Park.

HAWAIIAN HOSTS OF DACUS DORSALIS

Allspice (Pimenta dioica)
Apple (Pyrus malus)
Avocado (Persea americana)
Balsam apple (Momordica balsamina)
Banana (Musa nana, sapientum)
Bay rum (Pimenta racemosa)
Be-still tree (Thevetia peruviana)
Bitter melon (Momordica charantia)
Breadfruit (Artocarpus incisus)
Bullock's heart (Annona reticulata)
Bumelia buxifolia
Cactus, prickly pear (Opuntia megacantha)
Canistel (Lecuma nervosa)
Carambola (Averrhoa carambola)
Chebula (Terminalia chebula)
Cherry, Jerusalem (Solanum pseudocapsicum)
Cherry, Surinam (Eugenia uniflora)
Chestnut, Tahitian (Inocarpus edulis)
Coffee, berries (Coffea arabica, liberica)
Cotton (Gossypium barbadense)
Date palm (Phoenix dactylifera)
Dilly, wild (Mimusops elengi)
Fig (Ficus carica, retusa, macrophylla, rubiginosa)
Gooseberry, Ceylon (Doryalis hebecarpa)
Grapefruit (Citrus paradisi)
Guava, strawberry (Psidium cattleianum, cattleianum var. lucidum)
Inga laurina
Inkberry (Cestrum diurnum)
Kamani, ball (Calophyllum inophyllum)
Kamani, winged (Terminalia catappa)
Kumquat (Fortunella japonica)
Lemon (Citrus limon)
Lilikoi (Passiflora edulis)
Lilikoi yellow fruited (Passiflora laurifolia)
Lime (Citrus aurantifolia)
Litchee (Litchi chinensis)
Longan (Euphoria longana)
Loquat (Eriobotrya japonica)
Mabolo or velvet apple (Diospyros discolor)
Macadamia nut (Macadamia ternifolia)
Mammee apple (Mammea americana)
Mango (Mangifera indica)
Mangosteen (Garcinia xanthochymus)
Manilkara emarginata
Mock orange (Murraya paniculata)
Mountain apple (Eugenia malaccensis)
Mulberry, black (Morus nigra)
Ochrosia elliptica
Opiuma or Quamachil (Pithecolobium dulce)
Orange, Chinese (Citrus japonica var. hazara)
Orange, sour (Citrus aurantium)
Orange, sweet (Citrus sinensis)
Papaya (Carica papaya)
Passion flower, white-flowered (Passiflora subpeltata)
Passion flower, foetid (Passiflora foetida)
Peach (Prunus persica)
Pepino (Solanum muricatum)
Pepper (Capsicum frutescens var. grossum)
Persimmon (Diospyros kaki)
Pineapple (Ananas sativa)
Plum, damson (Chrysophyllum monopyrenum)
Plum, governor's (Flacourtia indica)
Plum, Madagascar (Noronhia emarginata)
Plum, hybrid (salicina x cerasifera)
Plum, Natal (Carissa gradiflora)
Polyalthea longifolia
Pomegranate (Punica granatum)
Pomelo (Citrus grandis)
Rose apple (Eugenia jambos)
Sandalwood (Santalum album)
Sapodilla (Manilkara zapotilla)
Sapota, white (Casimiroa edulis)
Sea-grape (Coccoloba uvifera)
Soursop (Annona muricata)
Star apple (Chrysophyllum cainito)
Strawberry (Fragaria spp. hybrids)
Tangerine (Citrus reticulata)
Ti (Cordyline terminalis)
Tomato (Lycopersicon esculentum)
Wi apple (Spondias dulcis, tuberosa)
Ylang ylang (Artobotrys uncinatus, Cananga odorata)
Yucca aloifolia
Zizyphus mauritiana

OBSERVATIONS ON HOST FRUITS

It is believed that, generally, fruits must be approaching maturity before oviposition succeeds. It has been observed that attempts are made to oviposit in immature fruits, but if the fruit is too hard the skin cannot be penetrated; if ripening has not begun the eggs will be expelled, crushed, drowned or vitiated by some deleterious element of the sap, e.g. a proteolytic enzyme.

The following data has been obtained on collections of infested fruits made during the course of one year, from June 1st, 1947, to June 1st, 1948.

Avocado (*Persea gratissima*) is not generally infested until mature and beginning to ripen but is then a favoured host, capable of supporting large numbers of larvae.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	5	5	15	3	3	
July	14	12	699	49·9	58	+ 3 *D. cucurbitae*
July	6	5	84	14	17	
July	5	5	116	23·2	23	
August	7	6	343	49	57	
August	4	6	265	66·2	44	
September	10	7	322	32·2	46	
October	5	5	160	32	32	
November	5	4	96	19·2	24	
December	6	3	2	0·3	0·6	
January	10	3	100	10	33·3	
February	6	4	0	0	0·3	*D. cucurbitae*
March	5	3	40	8	13	+ 22 *D. cucurbitae*
April	6	4	130	21·6	32·5	+ 10 *D. cucurbitae*
May	5	3	55	11	18	

Banana (*Musa nana*). There has been no export of bananas since 1941, at first on account of lack of shipping, lately on account of *D. dorsalis* infestation and federal quarantine. It is believed possible to avoid infestation of bananas by harvesting the bunches at mature green stage, cutting out and destroying any split or bruised fingers, and holding the bunches in a fly-proof shelter while ripening progresses.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	10	3	367	36·7	122	
July	12	3	123	10·3	41	
August	11	4	1	0	0	*D. cucurbitae*
September	20	3	31	1·6	10	
October	10	3	33	3·3	11	
	10	3	281	20·8	94	
	10	2	240	24	120	
November	6	2	2	0	1	
	5	1	8	1·6	8	
December	12	2	0	0	0	
	5	2	2	0	1	
January	10	3	151	15·1	50	
February	10	2	1,088	108·8	544	
	12	3	200	16·6	67	
March	15	3	93	6·2	31	
April	15	2	147	9·8	73·5	
May	17	4	17	1	4·25	
	6	1	20	3·7	20	

Breadfruit (*Artocarpus communis*) is not ordinarily infested until over-ripe, but if bruised, and soft rot develops, *D. dorsalis* will oviposit in the rotted part and a heavy infestation follows.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
July	5	5	447	89·4	90
September	2	2	60	30	30
October	2	10	130	65	13
November	1	4	30	30	7·5
February	2	4	2	1	0·5
April	1	3	695	695	232
May	1	3	122	122	41

Cactus prickly pear (*Opuntia megacantha*) is not a preferred host.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
July	11	3	35	3·2	12
September	10	3	7	0·7	2·3
October	6	4	0	0	0

Carambola (*Averrhoa carambola*) becomes infested only as it ripens.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
July	21	5	26	1·2	5·2
August	10	1	42	4·2	4·2
September	10	2	26	2·6	13
October	10	3	10	1	3·3
	10	1	30	3	30
November	7	1	46	6·6	46
December	7	2	26	3·7	13
January	5	1	6	1·2	1·2
	10	1	60	6	60

Surinam cherry (*Eugenia uniflora*).

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	30	0·5	21	7	42	+ 1 *C. capitata*
July	25	0·25	5	0·2	20	
August	13	0·25	32	2·5	128	
November	30	0·5	25	0·8	50	
January	50	0·5	56	1	112	
	50	1	16	0·3	16	
March	100	1	267	2·7	267	
April	215	2	533	2·5	267	

Coffee (*Coffea arabica* and *C. liberica*). *D. dorsalis* has been reared from coffee berries repeatedly but does not utilize this fruit to the same extent as the Mediterranean fruit fly does. The coffee berry is the only fruit in which the Oriental has not supplanted the Mediterranean fruit fly. We have two records.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
January	180	1	32	0·2	27	*capitata* also
March	160	1	0	0	45	*capitata* also

Date palm (*Phoenix dactylifera*). Although thousands of fruits have been collected no *D. dorsalis* was obtained and it is believed that such cases as have been reported represent extremely rare and off-chance occurrences.

Wild dilly (*Mimusops elengi*).

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	100	0·5	353	3·5	706	+198 *C. capitata*
July	200	1	45	0·1	45	+ 6 *C. capitata*
August	100	0·5	14	0·05	28	
May	175	1	22	0·12	22	

Fig (*Ficus carica*) is always a favoured host of Mediterranean fruit fly and is now generally infested by *D. dorsalis.*

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	10	1	33	3·3	33	+ 16 *C. capitata*
July	13	2	110	8·5	55	
August	12	1	91	7·6	91	
September	25	3	357	14·3	119	
October	10	1	50	5	50	
November	25	2	180	7·2	90	
December	20	2	553	27·7	276·5	
	15	1	202	13·5	202	
January	20	2	131	6·6	65·5	
February	20	2	344	17	172	
	11	2	287	26	143·5	
March	30	3	1,052	35	351	
April	20	2	1,126	56	563	
May	7	5	212	30	424	
	30	4	545	18	138	

Ceylon Gooseberry (*Doryalis hebecarpa*).

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
January	17	0·5	29	1·7	58

Guava (*Psidium* spp.) fruit is generally infested by *dorsalis,* more so in summer months. Cultivated varieties known as strawberry guava and waiawi are also infested and the records obtained are included under C for *cattleianum* and M for *molle.*

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	10	2	647	64·7	323	+ 3 *C. capitata*
July	54	6	258	4·8	43	+ 16 *C. capitata*
	30	4	1,794	59·5	448	
	7	1	117	16·7	117	
August	23	2	540	23·5	270	
	54	6	1,055	19·6	176	
	20	2	442	22·1	221	
	70	8	870	12·4	109	+ 8 *C. capitata*
September	20	3	571	20·8	190	+ 4 *C. capitata*
	20	3	326	16·3	109	
October	25	4	215	4·6	54	
	20	3	277	13·6	92	
November	20	3	716	35·8	239	
	15	2	187	12·5	93	
December	10	2	85	8·5	42·5	
	20	1	148	7·4	148	
	11	2	31	2·8	15·5	
January	20	2	42	2·1	21	
	25	3	95	3·8	32	
February	20	3	27	1·4	9	
	25	3	26	1·4	9	
March	13	2	9	0·7	1·5	
	25	3	328	13·1	109	
April	27	3	391	14	130	
	25	3	136	5·4	45	
May	10	1	391	39·1	391	
July C	40	0·5	349	8·7	698	
August C	85	1	469	5·5	469	
September C	100	2	590	5·9	295	
November C	20	0·5	188	9·4	376	
February C	100	2	340	3·4	170	
August M	200	3	750	3·7	250	
September M	50	1	58	1·2	58	
October M	50	1	150	3	150	
November M	25	0·5	100	4	200	
March M	100	2	73	0·7	36	

Ball Kamani (*Calophyllum inophyllum*) fruits are not generally infested and when they are, flies from them as usually depauperate individuals. We have two records of infestation.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
November	20	1	0	0	0
April	15	1	53	3·5	53

Winged kamani (*Terminalia catappa*) are generally heavily infested. C indicates *Terminalia chebula.*

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
August	25	2	0	0	0
	34	2	766	22·5	283
September	50	3	1,510	30·2	503
	50	3	922	18·4	307
October	25	2	85	3·4	42·5
	25	1	30	1·2	30
November	20	1	178	8·9	178
	20	1	766	33·3	766
December	10	1	117	11·7	117
	25	1	432	17·7	432
January	25	2	448	17·9	224
February	15	1	70	5	70
March	15	1	477	31·8	477
April	25	2	1,000	40	500
May	35	2	1,052	30	526
October C	60	1	338	5·6	338
November C	50	1	380	7·6	380

Kumquat (*Fortunella japonica*).

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
February	63	2	295	4·7	147·5
April	43	1	322	7·5	322
	55	1	430	7·8	430

Lemon (*Citrus limon*).

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
September	11	2	18	1·6	9
November	5	1	3	0·6	3
February	15	3	7	0·5	2

Lilikoi (*Passiflora edulis*) is occasionally infested, but is not a preferred host.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
July	14	2	0	0	0

Water lemon (*Passiflora laurifolia*). Occasionally infested.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
December	10	1	8	0·8	8
January	15	2	14	0·9	7

Lime (*Citrus aurantifolia*).

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
July	50	2	124	2·5	62

Litchee nut (*Litchi chinensis*). The litchee nut is not infested unless the shell-like covering of the fruit splits as the fruit reaches maturity; in the pulp thus exposed *D. dorsalis* has been known to deposit eggs.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	50	1	35	0·7	35	
July	143	3	75	0·5	25	
longan	94	1	10	0·1	10	+ 2 *D. cucurbitae*

Loquat (*Eriobotrya japonica*) was a favoured host of *capitata* and is also infested by *D. dorsalis* although not many records are available. Those that we have were obtained after *D. dorsalis* had supplanted *C. capitata* in most fruits.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
November	30	0·5	100	3·3	200
January	35	1	26	0·7	26
February	25	1	53	2·1	53
March	45	1	76	1·7	76

Mamee Apple (*Mammea americana*). Fruit becomes infested at maturity.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
June	10	7	31	3·1	4
July	6	4	0	0	0

Mango (*Mangifera indica*) is a favourite host of *D. dorsalis* and fruits generally become infested as they reach maturity. Some varieties of mangoes are believed less susceptible to attack than others but little data has been collected.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	10	3	80	8	27	
July	34	14	226	6·6	16	+ 3 *D. cucurbitae*
September	1	1	0	0	0	
November	10	3	396	38·6	132	
January	10	3	58	5·8	19	+ 1 *D. cucurbitae*
February	15	3	216	14·4	72	
March	10	3	349	34·9	116	
April	11	3	232	21	77	
May	10	3	334	33·4	111	

Mangosteens (*Garcinia mangostana* and *xanthochymus*) fruits do not become infested until ripe and are not preferred hosts.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
August	10	2	0	0	0
December	14	3	24	1·7	8
February	11	2	23	2	11·5
March	80	8	28	0·4	3·5
May	10	3	10	1	3

Mock orange (*Murraya paniculata*) fruits are preferred hosts.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
February	200	0·5	423	2·1	846
March	200	0·25	115	0·6	460
April	420	0·5	527	1·2	1054
	200	0·25	107	0·5	428

Mountain apple (*Jambosa malaccensis*) are very attractive to *D. dorsalis.*

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
June	12	2	132	11	66
July	37	1	200	5·4	200
	6	1	290	48·3	290
November	20	2	358	17·9	179

Mulberry (*Morus nigra*) fruit is frequently infested.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
March	50	0·25	69	1·4	276
April	185	0·5	40	0·2	80

Ochrosia (*Ochrosia elliptica*) fruit occasionally produce *D. dorsalis* flies but it is not a favoured host. Mr. Joseph Rosa of the H.S.P.A. Experiment Station reared the fly from this fruit.

Chinese orange (*Citrus japonica* var. *hazara*).

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
September	6	4·5	18	3·0	4
November	4	2	13	3·2	6·5
April	43	1	322	7·5	322
	55	1	430	7·8	430

Sour orange (*Citrus aurantium*).

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
October	8	4	6	0·75	1·5
December	5	2	7	1·4	3·5
January	5	2	21	4·2	10·5
February	10	4	285	20·9	71·25

Papaya (*Carica papaya*) fruit are attractive to *D. dorsalis* when ripened sufficiently to permit oviposition. Commercially grown fruits must be picked before properly ripe to be marketed without loss, but when market demands are light and regular picking is neglected or when trees become too tall to readily harvest the fruit, ripe fruit will receive many depositions of eggs and generally the deep and ample flesh is capable of sustaining a large number of worms to full maturity. Clean culture would do much to reduce fruit fly damage in commercial orchards.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	5	4	445	89	111	
July	5	4	131	26·2	33	
August	6	6	400	66·6	66	
September	4	5	382	95·5	76·4	
October	5	5	1230	246	246	
November	3	3	290	96·7	96·7	
December	3	3	70	23·3	23·3	
January	6	4	678	113	169·5	+ 1 *D. cucurbitae*
February	7	4	2110	301	527·5	
March	4	3	242	60·5	80·6	
April	4	5	191	48	40	
May	3	4	460	153	115	

Passion flower vine (*Passiflora foetida*) occasionally infested.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
July	47	0·5	0	0	0

Chile pepper (*Capsicum frutescens* var. *abbreviatum*) frequently but not generally infested.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
October	50	1	10	0·2	10

Persimmon (*Diospyros kaki*) and Philippine "mabolo" (*D. discolor*). *D. dorsalis* has been reared from both fruits, and *C. capitata* from *D. kaki*.

Damson plum (*Chrysophyllum monopyrenum*). A preferred host of *D. dorsalis* and formerly of *C. capitata*.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	100	1	12	0·12	12	+ 57 *C. capitata*
December	50	0·5	643	12·9	1286	
January	75	0·5	110	1·5	220	
February	100	0·5	642	6·4	1284	
April	155	2	978	6·3	489	
May	50	0·5	125	2·5	250	

Natal plum (*Carissa grandiflora*) fruits are very attractive to *D. dorsalis* but oviposition is difficult on account of milky sap exuded from puncture, and not one fruit out of a dozen will be found to contain mature larvae. Most fruits develop soft rot and fall to the ground where worms enter the soil to pupate. Thus, sizable populations are maintained continually around bearing bushes.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
June	20	1	65	3·3	65
July	77	2	111	1·4	55·5
August	40	1	20	0·5	20
	40	1	42	1	42
September	75	2	280	3·86	140
October	70	1	200	2·9	200
	20	1	3	0·2	3
November	50	1	100	2	100
December	22	0·5	6	0·3	12
January	50	1	70	1·4	70
February	30	1	7	0·2	7
March	40	1	9	0·2	9
April	35	0·5	2	0·05	4
May	30	0·5	20	0·75	40

Pomelo (*Citrus grandis*).

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
April	3	4	0	0	0

Rose apple (*Eugenia jambos*).

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	10	1	285	28·5	285	
July	50	2	1008	20·2	504	+ 2 *C. capitata*
	45	2	1641	36·5	820	
August	50	4	1732	34·6	433	
September	20	1	534	26·7	534	
February	20	2	350	17·5	175	
March	40	2	748	18	374	
April	25	2	205	8	102·5	
May	35	2	1052	30	526	

Sapodilla (*Manilkara zapotilla*) is not always infested but when *D. dorsalis* reaches it, oviposition is successful and the fruit support a large number of larvae.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
August	18	3	750	41·7	250
December	10	1	107	10·7	107
January	15	2	34	2·3	17
February	14	2	123	8·8	62
March	15	3	66	4·4	22
April	15	1	222	14·8	222

White sapota (*Casimiroa edulis*) fruits become infested when ripe.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
March	8	1	763	95	763
April	10	1	155	15·5	155
	40	2	103	2·6	51

Soursop (*Annona muricata*) fruit is not ordinarily infested until well grown, and is usually found in the markets in good condition. Under certain conditions (inattention to ripening) it may become heavily infested.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	2	4	24	12	6	+ some *C. capitata*
July	3	5	714	278	143	
November	1	2	122	122	61	
January	1	1	0	0	0	
February	2	4	1377	688·5	344·25	
March	1	0·5	0	0	0	

Star apple (*Chrysophyllum cainito*). The milky juice which exudes when the skin is broken prevents infestation to some extent.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
May	6	2	8	1	4

Tangerine (*Citrus reticulata*).

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.	
June	10	2	29	2·9	15	+ 1 *C. capitata*
August	10	2	259	25·9	129·5	+ 1 *D. cucurbitae*
October	7	1	242	34·5	242	
November	6	2	57	9·6	28·5	
December	15	2	98	6·5	49	
April	7	2	16	2	8	

Tomato (*Lycopersicon esculentum*) is apparently not very attractive to *D. dorsalis*. Others have reared the Oriental fruit fly from this fruit, both laboratory and field infested, but all of our collections yielded melon fly. *D. dorsalis* has been reared from pepino (*Solanum muricatum*) and Jerusalem cherry (*Solanum pseudocapsicum*).

Wi apple (*Spondias dulcis*) fruit is generally infested.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
September	25	2	47	1·9	23·5
October	34	6	475	13·9	79
November	10	2	80	8	40
December	10	3	24	2·4	8

Ilang-ilang (*Cananga odorata*) fruit is attractive to *dorsalis*.

	No. of Fruits	Weight lbs	Flies Reared	Flies per Fruit	Flies per lb.
June	20	0·25	224	11·2	892
March	70	1	702	10	702
April	160	1	1016	6·3	1016
May	40	0·5	502	12·5	1004

CONTROL

Many control measures followed in other fruit-growing countries appear inapplicable here on account of the abundance of wild fruits, often growing in inaccessible places, which maintain the fly population in spite of any repressive measures taken, e.g. clean culture was given a trial when the Mediterranean fruit fly appeared in Hawaii in 1910-11 but proved ineffectual; with its failure, recourse was had to biological control. Poisoned baits have been experimented with also, without pronounced benefit. DDT gives protection for at least one week on mango trees, but it has not been adopted generally in orchard practice. Trapping with the aid of lures has not given satisfactory results. Bagging or covering fruits, so that the fly cannot reach them, gives good results with mangoes and figs.

Biological Control. In view of the previous experiences with fruit fly control in Hawaii, referred to above, responsible authority decided to explore at once the possible benefits to be derived from the natural enemies of the fruit flies—parasites and predators—since much had already been learned with regard to the existence of many valuable enemies of the fruit flies in the Orient from reports of previous explorations. Furthermore, the feeling prevailed among local entomologists who had worked in the Orient that it was rather uncommon to find wormy fruits in oriental markets, and certainly there was nothing like the destruction that has been seen in Hawaii during the past year or two, indicating control of fruit flies there, which might with good fortune be duplicated here. Accordingly, the help of Dr. L. B. Uichanco, Dean of the College of Agriculture, University of the Philippines, was solicited, and in the early months of 1947 six shipments were made of fruit fly puparia obtained from local fruits at Los Banos, Laguna, viz. papaya, ilang ilang, Java plum (*Syzigium javanum*) and calios (*Streblus asper*). These yielded the well-known fruit fly parasites *Syntomosphyrum indicum* Silv., *Opius longicaudatus* (Ashm.) and *Opius persulcatus* (Silv.). Of these, *S. indicum* and *O. longicaudatus* reproduced in *D. dorsalis. D. persulcatus* did not although it had equal opportunity with the others and had great numerical superiority. (*O. persulcatus* has been propagated in *Dacus cucurbitae* and *Opius fletcheri*, the constant parasite of *D. cucurbitae*, has also been reproduced in *D. dorsalis*. Efforts to multiply the small number of parasites from Los Banos failed, but some parasites were liberated after they had been used repeatedly in cages stocked with *D. dorsalis*-infested fruits.)

Mr. Q. C. Chock was sent to the Philippines in July 1947 to continue the work, and in the following six months made 25 shipments of *Dacus* puparia, mostly out of guavas, from which the same parasites were obtained, and all our efforts to propagate and multiply the useful species failed. Mr. Chock sent in addition hundreds of males and females of a predator, the staphylinid beetle *Thyreocephalus albertisi*, which has been successfully propagated and liberated.

In 1948 Mr. Noel L. H. Krauss was sent to Malaya to continue the collecting and shipment of parasites and predators and to date (July 13th 1948) has made five shipments of *Dacus puparia* obtained principally from carambola, containing practically the same parasites, viz. *O. longicaudatus*, *O. persulcatus* and a species near *fletcheri* and in good numbers. Propagation is proceeding satisfactorily and some liberations have been made.

Opius longicaudatus (Ashm.), received from Los Bangos, P.I., reared in *Dacus dorsalis,* egg to adult 20 days in September-October, *Proc. H.E.S.,* 13 (2): 207-16.

Syntomosphyrum indicum Silv., received from Los Banos, P.I., reared in *Dacus dorsalis,* egg to adult 13 days in March.

Opius persulcatus (Silv.), received from Los Banos, P.I., propagation unsuccessful.

The following liberations have been made:

O. persulcatus, 7 females, *Opius sp.* (short ovipositor) 1 female, liberated Maunawili, Oahu, March 15th on ripe coffee under sleeve (which was removed two days later).

O. persulcatus 2 females liberated at Maunawili, Oahu, March 17th, in mock orange bush.

O. persulcatus 5 females, 8 males, liberated at head Waianae Valley, Oahu, in ripe guavas and coffee, April 8th.

O. persulcatus 13 females, 14 males liberated at head of Waianae Valley, Oahu, in ripe guavas and coffee, April 10th.

O. persulcatus 5 females liberated, April 11th, in a fig tree with tent over infested fruit, Manoa Valley.

O. persulcatus 3 females liberated, April 11th, in *Carissa* bushes at Lanikai, Oahu.

O. persulcatus 6 females, 3 males liberated in fig and mango trees Manoa Valley, Oahu, May 11th-13th.

O. longicaudatus 1 female liberated in fig and mango trees, Manoa Valley, Oahu, May 11th-13th.

O. persulcatus 2 females liberated on Old Pali Road, Nuuanu, August 26th.

O. persulcatus 8 females liberated at head of Waianae Valley, Oahu, August 26th.

O. persulcatus 8 females liberated at head of Waianae Valley, Oahu, September 19th.

Staphylinid predator (*Thyreocephalus albertisi*) 26 females and males liberated at head of Waianae Valley, Oahu, September 19th.

O. persulcatus 5 females liberated on *Carissa* (heavily infested) at Lanikai, Oahu, October 29th.

More than a decade ago, *Syntomosphyrum indicum* was successfully introduced into Fiji, and from there 50 individuals male and female were obtained here in 1938. These were propagated for many generations in *Ceratitis capitata* but were eventually swamped by the infiltration of *Tetrastichus giffardianus,* which itself has now disappeared with the elimination of the Mediterranean fly. *Opius longicaudatus* (Ashm.) occurs in Guam, Swezey having reared this species in 1936 from *Dacus ochrosiae* Malloch infesting *Ochrosia fruits.*[7] Four species of *Opius,* viz *formosanus* Fullaway, *maculipennis* Enderlein, *arisanus* Sonan and *makii* Sonan, three reared from *Dacus dorsalis,* are listed in Sonan's Notes on Braconidae and Ichneumonidae from Formosa, *Trans. Nat. Hist. Soc. Formosa,* XXII: 118-119 (1932).

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[7] Insects of Guam II, *Bishop Museum Bull. 189*: 226 (1946).

NOTES ON ENTOMOLOGICAL WORK IN THE PHILIPPINES SINCE 1939, WITH SPECIAL REFERENCE TO THE ORIENTAL MIGRATORY LOCUST (*LOCUSTA MIGRATORIA MANILENSIS* MEYEN)

By Faustino Q. Otanes, Bureau of Plant Industry, Manila[1]

The first paper by the writer presented in the Pacific Science Congress in 1939 was a brief review especially of applied entomological work in the Philippines since the Spanish regime up to 1939. This second paper gives the salient activities in agricultural applied entomology, particularly of the Bureau of Plant Industry, Department of Agriculture and Natural Resources, at Manila, and the College of Agriculture, University of the Philippines, at Los Baños, Laguna, from 1939 to the present, a period of about a decade.

Control Work Against the Oriental Migratory Locust

This insect is still one of the major pests of crops in the Philippines. Alarming outbreaks still occur, resulting in the destruction of more or less large areas chiefly of rice and corn, especially in Mindanao, where the insect is known to have its permanent breeding grounds or outbreak areas. However, invasions by huge devastating swarms are no longer general or country-wide, as were the case during the Spanish times and even during the early part of the American regime. People in the greater part of Luzon have not seen threatening dense migratory swarms for the last twenty years. That the Migratory Locust is not as destructive now as it used to be has apparently been due chiefly to better organized campaigns against the pest and more effective means of fighting it, especially within the last sixteen years in which poisoned baits, arsenical dust mixtures, and, lately, DDT-kerosene and DDT-oil emulsions have been used with success.

Outbreaks of the Oriental Migratory Locust occur at more or less irregular intervals. From the continuous records and charts of locust infestations of the Bureau of Plant Industry (formerly the Bureau of Agriculture), the following complete outbreak cycles have been definitely identified:

1919 to 1929
1932 to 1939
1941 to the present

Records of the cycle preceding the 1919-1929 cycle were apparently partial and when it started could not be definitely ascertained. From our studies in the Bureau of Plant Industry, the following information, among other things, about these outbreak cycles has been obtained:

1. There is an interval of one to three years between cycles, during which apparently only solitaries and loose or *transiens* swarms are found, the latter appearing later within the period.

2. The sporadic occurrences of these *transiens* swarms have so far proved to be a practical basis for predicting the probable beginning of an outbreak, that is, the appearance of dense devastating migratory swarms.

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[1] Charter Member, National Research Council of the Philippines.

By the middle of 1939 the remaining scattered swarms of the 1932-1939 outbreak cycle, which were then found in Southern Luzon, had been controlled. As in the case of the 1919-1929 outbreak cycle, there followed a locust-free interval of about a year and a half, that is the whole of 1940 and the greater part of the first half of 1941, when migratory swarms could no longer be found. However, late in 1940, small loose or *transiens* swarms and solitaries were found in a few provinces, namely: Cagayan, Isabela, Mindoro, and Occidental Negros. A similar swarm of *transiens* with solitaries was reported from Southern Ala Valley, Cotabato, in May, 1941, and in June 1941, one swarm was reported from Kabasalan, Zamboanga. In July, 1941, another swarm was reported from Lagao, Southern Cotabato, and subsequently, during August and September, 1941, swarms were reported from the provinces of Davao, Zamboanga, Bohol, Cebu, Masbate, Sorsogon, Tayabas (now Quezon), and Isabela. During November, 1941, another swarm was reported from Camarines Norte. In every case specimens were received from the Bureau of Plant Industry fieldmen and they were found to be mixtures of *transiens* and solitaries.

With the exception of those in Cotabato and in Davao, all the *transiens* swarms in the other provinces were soon exterminated by the people in the areas concerned under the direction of the Plant Industry personnel and local officials. During September, 1941, when the writer visited Cotabato, new *transiens* swarms had been found in other places therein. He observed that some components of swarms, especially in Southern Cotabato, were already showing migratory characteristics, such as depressed or saddle-shaped pronota (instead of convex or straight or keeled as in the case of *transiens* and solitaries) and the almost uniform migratory coloration (black and brick-red) of the hoppers. By November, 1941, reports of new swarms in different places in Cotabato had been received by the Bureau of Plant Industry.

To destroy the scattered incipient swarms in Cotabato and thus forestall a new outbreak, the Bureau organized scouting and control parties there. These had the active co-operation of the National Land Settlement Administration officials, who led the settlers in exterminating swarms in and near cultivated areas, leaving the hired scouters of the Bureau to devote their efforts to the destruction of swarms in the uncultivated areas. Early in December, 1941, Dr. Gonzalo Merino, Chief of the Plant Pest and Disease Control Division of the Bureau of Plant Industry, went to Cotabato for the purpose of intensifying the campaign, but to his misfortune, he was overtaken there by the war. He succeeded eventually in returning to Manila by hazardous means. The subsequent bombing and strafing by Japanese planes of many areas in the Philippines, including the National Land Settlement Administration headquarters at Southern Cotabato, paralyzed all locust control activities there and in Davao, as well as in other places where swarms were found later.

ANTI-LOCUST ACTIVITIES DURING THE JAPANESE OCCUPATION

The forced let-up in the campaign apparently had enabled incipient swarms to continue increasing unchecked, for during 1942 migratory swarms were reported to have invaded all the provinces of Mindanao, including some of those in the Visayas, especially Leyte, Bohol, and Cebu. Because of the lack of chemicals and transportation facilities, the Bureau of Plant Industry could not give assistance to the provinces infested. Thus only the usual mechanical methods of control, such as driving the hoppers into corrals and pits, beating the hoppers, and catching the flyers with nets were employed by the people, in relatively localized efforts to control the pest. However, in the agricultural colonies in Southern Cotabato under the National Land Settlement Administration, there were reported fairly well organized control activities directed mainly against the hoppers to protect the rice and corn crops. Besides lack of insecticides, such as white arsenic for preparing poisoned baits, adverse conditions of peace and order owing to intensified guerrilla activities prevented a general campaign against the locust according to existing anti-locust laws and regulations. The Japanese did not exert any pressure on the Bureau of Plant Industry personnel and provincial and municipal authorities to lead a more intensified general campaign against the locust.

LOCUST CONTROL AFTER THE LIBERATION OF THE PHILIPPINES

Although the Philippines were liberated early in 1945, intensive locust control was not begun until early in 1946. This was chiefly because of the lack of equipment, insecticides and funds. Civilian transportation facilities were still few and far between in 1945 and shipments of whatever supplies were available were often delayed. Late in 1945, there was an agitation in some official quarters for the use of airplanes to apply DDT against locust swarms. It was assumed that since the application of DDT from airplanes was effective against mosquitoes and flies, it would also be effective against the locust. After a prolonged negotiation, a U.S. Army C-47 plane was made available in July, 1946. Trials made on Cebu and Bohol, however, with this plane, using ordinary diesel oil with 5% technical DDT, which is the usual strength used by the U.S. Army against mosquitoes and flies, did not give satisfactory results. Only about 2 per cent of the hoppers on the areas sprayed were killed. One reason for this unsatisfactory result was that the spray mists from the airplane, although known to be effective against flies and mosquitoes, were apparently not strong enough to affect the locusts fatally. That this seemed to be so, was shown by the fact that when the spray was applied on hoppers with ordinary compressed air sprayers, the mortality obtained was practically 100 per cent. Another reason for the unsatisfactory results with the airplane spraying was that most of the hoppers were apparently not hit because they hid under the grasses whenever the plane swooped down to release the spray, and the swarms soon left having been little affected, if at all, by any DDT deposited on the vegetation in the sprayed area.[3]

Because of the intensive campaigns against the locust, with the large-scale use of poisoned baits, arsenical dust, and to a certain extent, oil emulsions containing DDT, the locust situation in the Philippines has greatly improved. This is shown by the fact that according to consolidated reports, there were during November, 1948, only four provinces and ten municipalities infested, with an estimated area of 47 hectares of locust eggs, 6·5 hectares of hoppers and 44·5 hectares of flyers, whereas, in 1946, the maximum corresponding figures were 15 provinces and 155 municipalities with 272 hectares of eggs, 13,266 hectares of hoppers and 1,578 hectares of flyers.

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[3] The Bureau of Plant Industry plans to continue these airplane trials on locusts, using more suitable types of airplanes and trying not only DDT but also certain other new insecticides developed after the war.

CONTROL OF OTHER INSECTS

During the two years preceding the Japanese invasion the Bureau of Plant Industry's entomology and plant pest control staff was occupied with the control of rice armyworms, particularly *Spodoptera mauritia,* rice borers (*Schoenobius incertellus* and *Scirpophaga innotata*), rice bug (*Leptocorisa acuta*), corn borer (*Pyrausta nubilalis*) and other insects, particularly those affecting fruit trees and vegetables.

During the Japanese occupation, the efforts of the Bureau of Plant Industry pest control personnel were especially devoted to helping the people control insects of vegetables and root crops. When the Japanese commandeered most of the rice, the people grew leaf and root crops, specially sweet potatoes, and even sidewalks in cities and towns were planted in these emergency crops. The sweet potato weevil, *Cylas formicarius,* became especially troublesome and the problem of its control assumed great importance.

The Japanese were mainly interested in the cultivation of rice, cotton and tobacco but gave most of their effort to that of cotton. Very early in 1945, the Japanese began to organize their own technical staff, especially for cotton growing, and encouraged Japanese companies to go into the extensive cultivation of that crop. Their efforts, however, were rather unsuccessful chiefly because of insects, particularly the leafhopper, *Empoasca flavescens,* which caused havoc in many plantations. The Japanese also introduced into the Philippines what were said to be high yielding varieties of rice, such as Taichu 65, but these were also found very susceptible to leafhoppers, particularly *Nephotettix apicalis* and *N. bipunctatus* and a delphacid, *Nilaparvata* sp. and therefore did not win favour among the farmers.

CONTROL OF PESTS OTHER THAN LOCUSTS AFTER LIBERATION

After the liberation, the work in which the help of the Bureau of Plant Industry was urgently sought was the control of insects on vegetables and truck crops. These were grown extensively as money crops, demand being heavy and prices several times prewar. The onion thrips (*Thrips tabaci*) and cabbage caterpillars of which there are least four species, *Crocidolomia binotalis, Plutella maculipennis, Pieris rapae* and *Prodenia litura,* were found especially troublesome. The U.S. Army authorities also sought the assistance of the Bureau of Plant Industry in the control of insects on several U.S. Army emergency truck farms to supply the armed forces with fresh vegetables.

For onion thrips, which threatened to wipe out onion plantations in Central Luzon, kerosene emulsion with DDT, prepared according to the following formula gave highly satisfactory results.

Kerosene	4 liters
DDT	700 grams
Soap	800 grams (later reduced to 300 grams)
Water	2 liters

The dilution used was one part of the stock solution to 30 parts of water by volume.

Because of the great demand for fruits, especially citrus and mangoes, and the exceptionally good incomes obtained by growers, control of citrus and mango insects was the subject of frequent consultations with the Bureau of Plant Industry entomology staff. Among these were the green bug (*Rhynchocoris serratus*), bark borer (*Agrilus occipitalis*) and rind borer (*Prays citri*) on citrus, the hoppers *Idiocerus clypealis* and *Chunra niveosparsa* on mango, and scale insects and mealy bugs attacking both citrus and mango, as well as other fruit trees.

In the combat areas in the Philippines[3] large numbers of coconut trees had been destroyed. The dead coconut trees, both fallen and standing, have become veritable breeding places for the black, or rhinoceros, beetle (*Oryctes rhinoceros*) and the problem of eradicating these large foci of infestation in order to protect the healthy trees is one of the greatest problems at present confronting the farmers. Government asistance on a much greater scale is being demanded, undoubtedly involving a big outlay.

Because of forced neglect of coconut plantations owing to the war a coconut disease, locally known as "kadang-kadang", which is apparently due to a virus (1947), has gained much headway in coconut plantations in Southern Luzon. Likewise mosaic and other diseases affecting abaca, one of the premier export crops in the Philippines, have become more serious especially in Mindanao. In both cases the insects, particularly leafhoppers and aphids, which serve or are under suspicion as vectors, are receiving more attention from entomologists and plant pathologists[4] in the Philippines.

ENTOMOLOGICAL RESEARCH IN THE PHILIPPINES

The most important published contributions of both the College of Agriculture and Bureau of Plant Industry up to 1939 were noted in the writer's 1939 paper. After that year the Migratory Locust as a research problem continued to receive preferential attention. One of the most important phases of the problem tackled was the delimitation of the permanent breeding grounds or outbreak centres of the insect, a more precise knowledge of which is basic to successful control. In 1939 a progress report by Dean Uichanco on his trip to Mindanao to study the ecology of the outbreak centres of the locust was published in the Proceedings of the National Research Council of the Philippines (1939). In this report he made the following statements as a result of his observations with respect to probable outbreak centres of the Migratory Locust in Mindanao:

> (1) "The open lands of Cotabato immediately adjoining the southern limits of Liguasan Marsh and Lake Buluan, a shrinkage in the volume of whose water during years when rainfall in that neighbourhood is scantier than normal might conceivably provide markedly augmented locust breeding areas in the temporarily dried-up beds. As a consequence, the size of the swarms presumably increases to the point of stimulating mass emigration.

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[3] Other combat areas in the Pacific, such as those of Saipan, Tinian, etc., are said to be also now worse affected by the black beetle problem and American entomologists have been sent to the Philippines and other countries to explore for parasites of the black beetle.

[4] Dr. G. O. Ocfemia of the College of Agriculture, University of the Philippines, and his students, have led in the investigation of the role of certain aphids and leafhoppers as vectors for abaca mosaic and certain other crop diseases.

> (2) Open lands, also of Cotabato, close to the Apo and Matumtum mountain ranges, at least along the foothills, where because of their apparently suitability to abaca culture, ideal conditions for locust-swarm perpetuation probably exists."

There had been previous statements regarding the outbreak areas of the Migratory Locust, such as those of Baker (1925), Mackie (Otanes, 1925 and 1938) and Merino (1935) pointing to Mindanao as a permanent breeding area (outbreak area) of the pest. Mackie pointed to the country back of Fort Pikit, Cotabato, as one of the probable permanent breeding places (outbreak centres) and Merino stated that "the island of Mindanao was suspected as a potential locust breeding ground", adding that "the present wide infestations (the 1935 infestations) in Mindanao, Visayas and Bicol regions, as a matter of fact, originated from some foci between Lanao and Bukidnon". This meant some places near or at the boundary of the two provinces. Although such statements had been made, Dr. Uichanco's 1939 report is the first data-supported statement pointing to certain sections of Cotabato as probable outbreak centres. Previously he had published other papers, supporting his view that the abaca and the Migratory Locust have similar ecological requirements.

Otanes (1940) added Central and Southern Cotabato as outbreak centres, basing his statements on records of the Bureau of Plant Industry of incipient swarms and on his field observations, and those of the Bureau of Plant Industry personnel and of old inhabitants or long-time residents of Mindanao, such as stockmen, farmers and officials.

In this paper (1940), Otanes also made an attempt to forecast the occurrence of a new outbreak within 1941 to 1943 or not far beyond, basing his prediction on the occurrence of sporadic *transiens* swarms in 1940. Previously, in 1931, he warned that the appearance of sporadic swarms in 1930 might indicate the presence of developing swarms in the uncultivated areas and that all concerned should be on the lookout for swarms coming from such areas. In each case, an outbreak occurred the following year.

The first painstaking investigation aimed at forecasting outbreaks, using as bases sunspot cycles, climatic data and chronicles of locust outbreaks and infestations, dating back over 365 years, should be credited to Dean Uichanco. One of Dean Uichanco's notable summaries in his paper (1936) in which he stressed the practical value of knowing definitely the appearance of a new outbreak, was as follows:

> "The intended goal of the present investigation is to work out a method whereby the course of locust outbreaks in the Philippines may be foretold with reasonable accuracy and sufficiently in advance either as a measure of reassurance when the locust cycle is receding or to allow for a timely execution of repressive steps while the cycle is in the incipient stages. Because of the complexity of the factors involved, considerable additional experience alone in the future trends of locust epidemics will enable us adequately to test the criteria and methods herein used and decide whether they are dependable enough to be worth adopting in practice."

Dean Uichanco also concluded that the average locust-free interval between outbreaks in the 365 years under review is 11 years, which probably nearly represents the master cycle in locust periodicity in the Philippines.

In their paper in 1940, Koidsumi and Ogasahara made the following deduction, among other things, from Dean Uichanco's paper referred to:

"Suppose the correspondence between the cycle of locust outbreaks and 11-year average interval of sunspot minima which was found by Professor Uichanco from the past secular records thereof goes well in future, the next widespread infestation, which is now at its lowest point in the present cycle, is expected to occur in about 1944-1945 in the Philippines . . ."

As regards research work on other insects, the following list has been furnished to the writer by Dr. S. M. Cendaña and Dr. G. B. Viado, in response to his letter to Dean Uichanco, and shows the varied activities in this respect of the entomology staff at the College of Agriculture at Los Baños, carried out in addition to their teaching duties:

RESEARCHES FROM 1939-1947 (PUBLISHED AND UNPUBLISHED)

(a) *Systematic:*

1. Uichanco, Leopoldo B. A new species of *Odoiporus* (*Curculionidae*) from abaca in Mindanao.
   The material and illustrations were burned when the Japanese set the College of Agriculture buildings on fire in February, 1945.
2. Uichanco, Leopoldo B. Revision of the genus *Ectenus*.
   Material also burned.
3. Uichanco, Leopoldo B. A report on Moluccan butterflies collected by the Fairchild Expedition.
   The entire material and manuscript were also burned.
4. Uichanco, Leopoldo B. The Philippine components of the hemipterous family *Pentatomidae*.
   Manuscript and material burned.
5. Uichanco, Leopoldo B. Distributional notes on the endemic cicadid genus *Psythirystia*.
6. Viado, C. B., 1939. External anatomy and diagnostic characters of some common Philippine white grubs. Philippine Agriculturist, 18: 339-390.

(b) *Economic:*

1. Uichanco, Leopoldo B., 1940. Insect defoliators of cinchona in Mindanao. The Philippine Journal of Forestry 3: 45-49 1 plate.
   Seven species of leaf-eating weevils are considered, all belonging to the subfamily Brachyderinae, tribe Pachyrrhynchini. One interesting feature that these species have in common is that they represent either highly endemic or very restricted forms in their geographical distribution and they presumably originally fed on autochthonous plant species, taking to the quinine after this plant was introduced into the Bukidnon area. A general discussion is made of the probable origin of part of the agricultural pests in the Philippines.
2. Cendaña, Silverio M. A report on the insect pests affecting cultivated plants in Mindanao.
   This report was based on field observations made by the author in 1940 in the provinces of Bukidnon, Misamis Oriental, Misamis Occidental, Lanao, Cotabato, Davao and Zamboanga, involving rice, corn, sugar cane, abaca, banana, cacao, caimito, durian and certain other fruit trees, and ornamental plants.

The field notes as well as the manuscript were burned in 1945.

4. Cendaña, Silverio M. and Valeriano C. Calma. The efficacy of sawdust-carried kerosene in the control of the rice armyworm caterpillar on rice seedlings.

   Kerosene-impregnated sawdust was broadcasted from the dykes after the field has been flooded to submerge the young plants. The caterpillars were successfully killed, with the plants showing but slight leaf-tip "burns" which become practically unnoticeable four days after the treatment. A very practical method of armyworm control where fields could be submerged because it does not necessitate spraying or dusting equipment, and obviates the inevitable trampling of some of the seedlings were spraying or dusting resorted to.
5. Phermajavalit, N. & S. Cendaña. Comparative susceptibility of milled and unmilled rice storage to *Calandra oryzae* Linn., with a consideration of the biology of the pest in the Philippines. The material and manuscript were burned.
6. Cendaña, S. M. & Clare R. Baltazar, 1947. A biological study of *Empoasca flavescens* Fabr. (*Cicadellidae, Homoptera*). Philippine Agriculturist, 31 (1): 1-22.

(c) *Entomophagous Insects:*

1. Uichanco, Leopoldo B. & Silverio M. Cendaña. Host known entomophagous insects of the Philippines.

   A comprehensive list of entomophagous insects and their known hosts, based mostly on material reared in our laboratory since 1918, and including other entomophagous Philippine species with known hosts reported by previous workers.

   Notes, manuscript and material burned.
2. Cendaña, Silverio M. The Natural enemies of *Saissetia oleae* Bernard in the Philippines.

   This was published in one of the bulletins of the National Research Council of the Philippines.
3. Maclang, Felipe A. & S. M. Cendaña. Biology of the Chalcid parasite of *Calandra oryzae* Linn.

   Manuscript and material were burned, in 1945.

For our own part in the Bureau of Plant Industry, Manila, the following list shows the papers published since 1939 and manuscripts that had been completed but lost when the Bureau of Plant Industry buildings were burned by the Japanese:

1. Otanes, F. Q. & F. L. Butac, 1939. Cotton pests in the Philippines. The Phil. Journal of Agriculture, 11: 403-430.
2. Otanes, F. Q. & L. T. Karganilla, 1940. Insect and other pests of corn. The Phil. Journal of Agriculture, 11: 403-430.
3. Otanes, F. Q. & P. Sison, 1941. Pests of rice. The Phil. Journal of Agriculture, 12: 211-259 (Revised and republished in the same Journal, 13: No. 1 (1947): 36-88.
4. Otanes, F. Q., 1941. Plant pest and disease control in the Philippines (accomplishments and problems). Dept. of Agriculture and Commerce Yearbook, Manila.

5. Agati, J., P. Sison & R. Abalos, 1941. Rice maladies with special reference to the "stunt or dwarf" disease. Phil. Journal of Agriculture, 12: 197-210 (pathological and entomological).
6. Gonzales, S. S. A progress report on the biology and control of the larger lanzon bark borer. Published in the Phil. Journal of Agriculture.
7. Soriano, P. Observations on the biology and control of the Philippine field rat, *Rattus mindanensis mindanensis* Mearns. Published in the Phil. Journal of Agriculture.
8. Sison, P. Studies on rice borers.
   Manuscript was burned.
9. Sison, P. The rice leaf folder *Cnaphalocrosis medinalis*.
   Manuscript burned.
10. Ponce, A. The cucurbit leaf roller *Glyphodes indica*.
    Manuscript burned.
11. Gonzales, S. S. The development of the Giant Toad *Bufo marinus*.
    Manuscript burned.
12. Soriano, P. Food habits of the Chinese starling, *Aetheopsar cristatellus*.
    Manuscript burned.
13. Otanes, F. Q. & F. L. Butac. The Gall Chermid of Macopa.
    Manuscript burned.
14. Butac, F. L. The application of derris-"gaw-gaw" and calcium arsenate-"gaw-gaw" on cotton flowers.
    Manuscript burned.
15. Morrill, A. W. & F. Q. Otanes, 1947. DDT emulsion to control mealy bugs and scales. Journal of Economic Entomology, 40 (4): 559.
16. Otanes, F. Q., 1948. Notes on orchid pests and suggestions for their control. The Philippine Orchid Review, Vol. 1, 12-18.

WORK ON BENEFICIAL INSECTS

Biological Control

The egg parasite, *Trichogramma minutum*, was introduced from the United States in 1934 by Doctor Merino of the Bureau of Plant Industry and was reared and liberated in large numbers before and during the Japanese occupation. It is apparently established at least in the Manila area, as it was reared early in 1948 from the eggs of *Remigia archesia*, a local noctuid, the caterpillars of which attack soybeans. A predator, the Giant Toad (*Bufo marinus*), also introduced from Hawaii in 1934 by Dr. Merino, has been observed in numbers in Mindoro, Laguna, Negros and Iloilo, showing that it is established.

Mr. Quan C. Chock, an entomologist from Hawaii, who was in the Philippines in 1947 in search of parasites of the fruit fly *Dacus dorsalis*, reared specimens of *Opius fletcheri* from the pupae of the melon fly *Dacus cucurbitae*, indicating that the parasite is established in the Philippines. A number of these parasites[5] were introduced by the writer from Hawaii in 1923, multiplied in the laboratory and liberations were made in Manila, Bataan, Rizal and other provinces.

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[5] The parasites were furnished by Messrs. Fullaway and Chock of the Entomological Staff of the Hawaii Board of Agriculture and Forestry.

Beekeeping

The Bureau of Plant Industry purchased a few Italian bee colonies from a California beekeeper sometime in 1938. The Bureau had increased these to more than forty colonies and had sold several to private persons who were interested in beekeeping. Both extracted and section comb honey were successfully raised in the Manila area. However, all these bees perished during the liberation battles in Manila in 1945, some by fire and others through looting by Japanese soldiers. In view of the encouraging results obtained, the importation of new colonies of Italian bees is contemplated.

CONCLUDING REMARKS

As is also true in other lines of scientific work in the Philippines, the war wrought havoc, or dealt a serious blow, to entomological research through the total destruction of all the most important scientific libraries and likewise of insect collections, especially those of the National Museum, the College of Agriculture and the Bureau of Plant Industry. It will take many years to replace or rebuild these. In the case of the older literature in entomology, many may be replaced with difficulty and others may never be replaced at all, especially as former sources of the publications in Europe may have gone out of existence. In the meantime investigators in the Philippines on the systematic, biological and economic aspects of entomology have to labour under extreme difficulties.

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(3) KOIDSUMI & OGASAHARA, 1940. The Philippine Locust and its relation to Taiwan (A climato-ecological consideration), *Journal of Tropical Agriculture*, Japan, 12, No. 4 (December).

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(5) OTANES, F. Q., 1925. Insects: their relation to man and their control, *The Philippine Agricultural Review*, 18, 4: 373-410.

(6) OTANES, F. Q., 1932. Locust infestations in 1930 and their origin. Bureau of Plant Industry Contributions to knowledge of Philippine Agriculture, 1931. Bureau of Printing, Manila.

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NOTES ON ECONOMIC INSECTS OF MICRONESIA[1, 2]

By R. G. Oakley, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, United States Department of Agriculture

The accompanying notes on insects attacking cultivated plants in the Micronesian islands were largely assembled in 1946, while the author was a member of a survey party sent to these islands to acquire information on their economic problems. All the islands except Guam were formerly under the Japanese Mandate. Brief field observations of insects were made on the following 20 high islands and atolls, which were probably more or less representative of the three groups of islands: Caroline Islands (Hall Islands, Kapingamarangi Atoll, Kusaie, Nukuoro Atoll, Palau Islands, Ponape, Truk, Ulithi Atoll, Woleai Atoll, and Yap); Mariana Islands (Guam, Rota, Saipan, and Tinian); and Marshall Islands (Ailinglapalap, Eniwetok, Jaluit, Kwajalein, Likiep, and Majuro).

The entomological survey, supplemented by observations of the author while stationed on Guam in 1937-39, revealed that at least 200 species of plant-feeding insects associated with the principal field, fruit, and vegetable crops were to be found among the islands. Pests of the greatest apparent importance at the time, most of which represent introduced species, are briefly discussed, being grouped according to their host plants. Their distribution among the islands, as currently known from available identifications of material collected, is also indicated. Published information has been included, as well as host and distribution records furnished by H. K. Townes, a member of the survey expedition, and distribution data cited in the notes by K. L. Maehler and D. T. Langford, who visited the islands in 1947 for other organizations.

Pests of Field Crops

Cassava

Plantings of cassava (*Manihot* sp.) were commonly found throughout the high islands and frequently in the atolls. Except for occasional severe attacks on old canes by coccids, *Pseudaulacaspis pentagona* (Targ.) (Palau Is., Truk; Guam and Saipan) and *Saissetia nigra* (Nietn.) (Kusaie, Palau Is., Truk; also Ponape (Takahashi 1939, p. 263); Guam, Saipan, Tinian), the crop was not molested by insect pests. The coccids were common to many host plants.

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[1] The work was done at the request of the U.S. Navy under the immediate direction of the U.S. Commercial Company.

[2] Members of the Division of Insect Identification assisted in identifying the insects named in this paper.

Corn, Sorghum, and Sugarcane

Corn (*Zea mays*) was little encountered in Micronesia, except in the Marianas, where it is an important food crop. A few widely scattered patches of sorghum (*Sorghum* sp.) were observed on several islands. Sugarcane (*Saccharum officinarum*) was more plentiful. Stools and small patches for native consumption were scattered on many of the islands, and large acreages of old and abandoned cane were present on Saipan and Tinian.

Ancylonycha mindanaona Brske. (Scarabeidae) (Guam), grubs, were found to attack roots of young corn and grasses severely on occasions in 1937-39. The adults likewise were sometimes destructive to corn and to many trees during the March to May swarm season. *Anomala sulcatula* Burm. (Guam, Saipan, Tinian), a second scarab beetle, recorded as an important pest of sugarcane in the Marianas (Esaki 1940, p. 410), was found lightly damaging corn roots on Guam in 1937.

Aphis maidis Fitch (Palau Is., Ponape, Truk, Yap; Guam, Rota, Saipan, Tinian), the corn leaf aphid, was often abundant on corn and sorghum on Saipan and Rota, and to some extent on corn and sorghum on Truk.

Crambus spp. (Crambidae) (Guam), larval stalk borers, were found on one occasion severely damaging a planting of young corn.

Heliothis armigera (Hbn.) (Phalaenidae) (Guam; Eniwetok) was very destructive to sweet corn, and also injurious to the native variety of corn. These plants were similarly infested by *Heliothis* sp. (possibly *H. armigera*) (Rota, Saipan, Tinian).

Locusta migratoria L. (Acrididae) (Truk; Guam, Rota, Saipan, Tinian; Kwajalein, Majuro) was found to have destroyed a few fields of corn and also to be damaging sugarcane. Two other acridids, *Aiolopus tamulus* (F.) (Guam, Rota, Saipan, Tinian; Eniwetok, Kwajalein) and *Oxya intricata* (Stal) (Ponape, Truk), were also slightly damaging both corn and sugarcane.

Marasmia trapezalis (Guen.) (Pyraustidae) (Truk; Guam, Rota, Saipan, Tinian), a leaf roller, was seldom absent in young corn of the Marianas; yet important infestations were not observed. It attacks *Paspalum* spp.

Neomaskellia bergi (Sign.) (Aleyrodidae) (Nukuoro, Palau Is., Truk; Yap; Guam, Tinian), though commonly found on sugarcane, and occasionally on sorghum and several grasses, was of minor importance. Larvae of a predaceous phycitid, *Cryptoblabes* sp., were effecting some control of the species on Truk.

Peregrinus maidis (Ashm.) (Delphacidae) (Palau Is., Yap; Guam, Rota, Saipan, Tinian), the corn leaf hopper, was present in all plantings of corn examined on these islands, but was not destructive.

Phytomyza sp. (Agromyzidae) (Guam, Rota, Saipan, Tinian), leaf-mining larvae, were destructive to dry-season plantings of young corn that, however, appeared to recover largely from the attacks as it grew in size, especially when rainfall became abundant.

Prodenia litura (F.) (Phalaenidae) (Kusaie, Ponape, Truk, Woleai; Guam, Rota, Saipan, Tinian; Ailinglapalap, Eniwetok, Jaluit, Kwajalein), a general feeder, was observed a few times damaging corn and sorghum, but older, previously infested, stalks appeared to be recovering from the attacks.

Pseudococcus boninsis (Kuw.) (Coccidae) (Palau Is., Truk, Woleai; also Guam (Swezey 1940, p. 165)), attacking both sugarcane and sorghum in sparse infestations, was sometimes important. *Trionymus sacchari* (Ckll.) (Kusaie, Nukuoro, Palau Is., Ponape, Truk; Guam, Rota, Saipan, Tinian), the sugarcane mealybug, was ever present on sugarcane, but infestations did not appear to be very troublesome.

Pyrausta nubilalis (Hbn.) (Palau Is. (Langford, 1947), Yap; Guam, Rota, Saipan, Tinian), the European corn borer, was extremely destructive to corn on Yap and Saipan, but injury was light on Guam and Rota, where attacks were apparently minimized by an introduced parasite, *Lydella grisescens* R.D., which was also present on Saipan.

Rhabdoscelus obscurus (Bdvl.) (Curculionidae) (Kusaie, Palau Is., Truk, Ulithi, Woleai, Yap; Guam, Saipan, Tinian; Ailinglapalap) was only moderately destructive to sugarcane observed in the survey, though it was severe to Guam plantings in 1937-39.

Miscellaneous pests of corn included the African snail, *Achatina fulica* (Fer.) (Palau Is., Ponape, Truk; Guam, Rota, Saipan, Tinian), which, although a much reported pest of crops, was not otherwise found damaging cultivated crops.

Cotton

Occasional wild cotton plants (*Gossypium* sp.) found on all the high islands surveyed, and a few small patches abandoned on Saipan and Rota, represented all the cotton observed.

Aphis gossypii (Glov. (Kapingamarangi, Kusaie, Palau Is., Ponape, Nukuoro, Truk, Yap; Guam, Rota, Saipan, Tinian; Ailinglapalap, Eniwetok, Jaluit, Kwajalein, Likiep, Majuro) was seen on cotton a few times.

Earias sp., possibly *fabia* Stoll (Phalaenidae), (Guam, Tinian), a bollworm, was found infesting occasional cotton squares and okra (*Hibiscus esculentus*) to a minor degree.

Oxycarenus bicolor Fieber (Guam, Saipan) (Lygaeidae) was abundantly infesting open bolls.

Pectinophora scutigera (Hold.) (Gelechiidae) (Guam, Rota, Saipan, Tinian), a bollworm, infested as much as 5 per cent of the green bolls.

Rice

Several small plantings of rice (*Oryza sativa*) were encountered on Rota, as were occasional plantings on Ponape and Truk. Several hundred acres of the crop were cultivated annually on Guam in 1937-39.

Aiolopus tamulus (F.) and *Oxya intricata* (Stal) (see Corn, etc.) were abundant in rice fields observed in their respective ranges, causing considerable damage to rice grains in the milky stage. Tettigoniids in similar infestations were *Conocephalus longipennis* (Haan) (Truk, Ulithi; Rota, Tinian) and *Conocephalus* sp. (Ponape, Truk).

Leptocorisa acuta (Thunb.) (Coreidae) (Palau Is., Truk; Guam, Rota) attacks on immature rice grains were severe. Swarms of the insect, which breeds on several grasses, were general in rice fields.

Nephotettix bipunctatus (F.) (Cicadellidae) (Guam), a leafhopper, was ever present on rice in 1937-39, but generally of minor importance.

Nezara viridula (L.) (Pentatomidae) (Palau Is., Ponape, Truk; Guam, Rota, Saipan, Tinian) was abundant on rice on Rota.

Nilaparvata lugens (Stal) (Delphacidae) (Guam) was found on rice in immense populations in 1938. Its eggs were attacked by a predaceous mirid, *Cyrtorhinus lividipennis* Reut. *Nilaparvata* sp. (possibly *N. lugens*) was also collected from rice on Rota.

Susumia exigua (Butl.)? (Pyraustidae) (Guam, Rota), a leaf folder, had damaged about half of the leaves in the Rota rice fields observed. It was often equally as severe, and sometimes more so, to rice on Guam in 1937-39. *Brachymeria* sp. was reared from this leaf folder on Guam.

Sweetpotato

Plantings of sweetpotatoes (*Ipomoea batatas*) were plentiful on all the high islands and on many of the atolls as well.

Cylas formicarius (F.) var. (Curculionidae) (Palau Is., Ponape, Truk, Ulithi, Yap; Guam, Rota, Saipan, Tinian) attacks were sometimes severe to both stems and sweetpotatoes.

Daealus sp. (Curculionidae) (Palau Is., Woleai, Yap; Rota) was destructive to stems and sweetpotatoes in one Rota area, but was of only slight importance in other islands where it was observed. The species was also reared from lemon fruit.

Euscepes postfasciatus (Fairm.) (Truk; Guam, Rota) and *Euscepes* sp. (Curculionidae) (Palau Is., Ponape, Yap) were severe on sweetpotatoes in many Truk fields, but injuries were light elsewhere.

Halticus tibialis Reut. (Miridae) (Kusaie, Palau Is., Ponape, Truk, Ulithi, Yap; Jaluit) attacks on sweetpotato leaves and stems were frequently severe, especially on Kusaie, Ponape, and Truk, but were of a minor nature on Palau Island and Yap. The species was also taken from *Luffa* sp., *Vigna marina*, and *Hibiscus sabdariffa*.

Lyonetiidae (Palau Is., Ponape, Truk, Woleai, Yap) leaf-mining larvae were abundant on sweetpotatoes of Woleai and Truk, but were scarce elsewhere. Two or more species of wild *Ipomoea* served as alternate hosts.

Prodenia litura (F.) (see Corn, etc.) larvae were observed several times damaging leaves of sweetpotato in the Marshalls.

Taro

One or more varieties of taro (*Alocasia*, *Colocasia*, and *Cyrtosperma*), a chief food crop of Micronesia, were found in all the islands surveyed.

Aphis gossypii Glov. (see Cotton) was extremely abundant on *Colocasia* on Nukuoro, apparently in the absence of predators, but was only moderately important to taro elsewhere. *Aphis* sp. (Truk; Rota, Saipan) was observed in abundant populations.

Megamelus prosperpina Kirk. (Delphacidae) (Kusaie, Nukuoro, Palau Is., Ponape; also Truk (Esaki 1940, p. 411); Guam, Rota; Majuro) attacks were severe to *Colocasia* on Ponape and Nukuoro, but were only moderately important to that host on other islands. A predaceous mirid, *Cyrtorhinus lividipennis* Reut., aided in keeping down populations on the Marianas.

Prodenia litura (F.) (see Corn, etc.) was occasionally found damaging leaves of both *Colocasia* and *Cyrtosperma.*

Tobacco

Scattered dooryard plantings of tobacco (*Nicotiana tabacum*) were present in many of the islands. The plants observed were little damaged by insects, as a rule, although moderate damage, attributed to both *Heliothis armigera* (Hbn.) and *Prodenia litura* (F.) (see Corn, etc.), was observed a few times. *Cyrtopeltus tenuis* Reut. (Miridae) (Hall Is., Ponape, Yap; Guam, Rota, Saipan, Tinian) was common on tobacco in minor attacks.

Yam

Though reported an important food crop in the high islands, yams (*Dioscorea* sp.) were little seen in the survey. *Chrysodeixis chalcites* (Esp.) (Phalaenidae) and *Adoxophyes angustilineata* (Wlsm.) (Tortricidae), both general feeders, were observed in miscellaneous leaf infestations on Guam, while on Ponape unidentified lepidopterous larvae were also seen on leaves.

Pests of Fruit Crops

General

Fruit Flies (Tephritidae)

Dacus dorsalis Hendl. (Guam (Maehler 1947), Rota, Saipan, Tinian) was seriously infesting fruits of *Persea americana, Psidium guajava, Mangifera indica, Carica papaya, Annona muricata,* and *Terminalia catappa.* Ripe fruits of *Artocarpus altilis* were also infested, but not seriously. Fruit of other possible normal hosts was not encountered.

Dacus frauenfeldi Schin. (Kapingamarangi, Kusaie, Truk, Woleai, Yap; Ailinglapalap, Jaluit, Likiep, Majuro), a fruit fly, was reared from ripe fruits of *Artocarpus altilis, Calophyllum inophyllum, Syzygium malaccensis, Guettarda speciosa, Mangifera indica, Ochrosia* spp., and *Psidium guajava.* Attacks on mango were severe in some cases and light in others, while damage to breadfruit was of slight importance.

Dacus ochrosiae Mall. (Guam, Saipan, Tinian) was reared abundantly from fruits of *Aglaia marianensis, Syzygium jambos, Eugenia* sp., *Malpighia glabra, Ochrosia* spp., *Terminalia catappa,* and *Ximenia americana.* Its economic importance was not established.

Avocado

Scattered trees of avocado (*Persea americana*) were encountered on Guam, Saipan, and Ponape. Mature green fruit on Saipan was 100 per cent infested with larvae of *Dacus dorsalis* Hendl. (see Fruit Flies), although leaves were sometimes infested with patches of *Aspidiotus destructor* Sign., (see Coconut). Another coccid (*Aspidiotus palmae* Ckll.) (Kusaie, Palau Is., Ponape, Yap; also Truk, Saipan (Takahashi 1941, p. 220)) heavily infested leaves on Ponape.

Banana

Bananas (*Musa* sp.) in scattered plantings were common to all the islands surveyed.

Ancylonycha mindanaona Brske. (see Corn, etc.) adults were found skeletonizing leaves in attacks of some slight importance.

Cosmopolites sordidus (Germ.) (Curculionidae) (Kusaie, Palau Is., Ponape, Truk, Woleai, Yap; Guam, Saipan) attacks on bananas were severe on Kuasie, and were reported to have made the production of many banana strains impossible on Ponape, although it was seldom seen there during the survey. Infestations were general in other islands, but not severe. *Polytus mellerborgii* (Boh.) (Truk (Maehler 1948); Guam, Saipan), another weevil, apparently of slight significance, accompanied the attacks by *C. sordidus.*

Other banana insects included an unknown species of the Palau Islands which was responsible for the scabby appearance of about 10 per cent of mature green fruits observed; also five species of scales and two Acrididae of minor significance.

Breadfruit

Breadfruit (*Artocarpus altilis*), a staple food crop of all the islands surveyed in Micronesia, was abundant everywhere.

Aclees porosus Pasc. (Curculionidae) (Palau, Yap), larvae, together with larvae of a pyraustid (not yet identified), were infesting up to 90 per cent of the terminal buds of breadfruit on the Palaus.

Aspidiotus destructor Sign. (see Coconut) frequently almost covered the undersides of all leaves of trees growing in clearings on many islands, but was rarely found on thickly planted trees.

Icerya aegyptiaca Dougl. (Coccidae) (Hall Is., Truk, Ulithi, Yap; Guam, Rota, Tinian; also Palau Is., and Saipan, Takahashi 1936, p. 175); Ailinglapalap, Jaluit, Likiep; also Kwajalein (Maehler 1948)) was very abundant and destructive to breadfruit leaves of the Hall Islands, one Truk islet, Ulithi, and the Marshall Islands infested, but was unimportant in other islands, where an undiscovered predator was apparently keeping it under control. It attacked many other food plants, including *Ficus*, *Citrus*, coconut, *Euphorbia,* banana, croton, *Alocasia,* and *Pandanus.*

Dacus dorsalis Hendl. and *D. frauenfeldi* Schin. (see Fruit Flies) were slightly damaging to ripe breadfruit.

Additional insects affecting breadfruit included six species of coccids, seven species of derbids, a leaf beetle, a weevil, and an aleyrodid.

Citrus

Citrus trees were scattered generally throughout most of the islands.

Agrilus occipitalis (Esch.) (Buprestidae) (Guam, Rota, Saipan, Tinian) adults feeding on leaf edges and tender twigs were responsible for important damage on occasional trees.

Papilio xuthus L. (Papilionidae) (Guam, Rota, Saipan, Tinian) larvae were observed to cause slight injury to tender leaves.

Phyllocnistis citrella Staint. (Tineidae) (Palau Is.; Guam, Rota, Saipan, Tinian), the citrus leaf miner, was commonly found damaging new foliage and tender shoots in infestations of moderate importance.

Prays sp., probably *endocarpa* Meyr. (Hyponomeutidae), (Palau Is., Yap), which attacks the rind of both immature and ripe fruits, forming galls on the former, was the most important citrus insect encountered. A large percentage of fruits were infested, though oranges were attacked less than lime, pomelo, and lemon.

Scale infestations were severe on occasional citrus trees in most of the islands, but were sparse or absent on most of the trees observed. The species listed below were responsible for all important infestations observed, 14 additional species taken from citrus being of slight importance at most.

Adonidiella inornata McKenzie (Ponape, Truk, Yap; Guam, Ailinglapalap, Jaluit, Kwajalein, Majuro; also Oleai (Takahashi 1939, p. 270)).

Chrysomphalus aonidum (L.) (Ponape).

Lepidosaphes gloveri (Pack.) (Ponape, Truk; Guam, Saipan).

Parlatoria cinerea Hadden (Guam; also Saipan (Takahashi 1939, p. 269)).

Parlatoria proteus Curtis (Kusaie, Nukuoro, Ponape, Truk, Yap; Guam; also Palau Is. (Takahashi 1936, p. 117)).

In addition to these insects, an unknown fruit-sucking moth, possibly *Ophideres fullonia* (Clerck), (Esaki 1940, p. 413), was somewhat damaging on Kusaie.

Coconuts

Large acreages of coconuts (*Cocos nucifera*) occur on the high islands, while the atolls surveyed are practically covered with them.

Acanthograeffea denticulata (Redt.) (Phasmidae) (Guam, Rota, Saipan) was destructive to leaves in many localities. Typical phasmid feeding injuries, mostly of slight importance and possibly due in some cases to *A. modesta* Gunther and to *Graeffea coccophaga* Newp. (Truk and Ponape, respectively (Esaki 1940, p. 409)), were common on the Hall Is., Ponape, Truk, Ulithi, and Yap.

Agonoxena ? sp. (Agonoxenidae) (Kusaie, Nukuoro; Guam) larval feeding was important on older fronds in many localities. Their feeding in straight lines near the midrib of leaves caused many of the leaves to split. Larvae on Guam were parasitized by *Brachymeria hammari* Cwfd.

Brontispa mariana Spaeth (Chrysomelidae) (Hall Is., Truk; Rota, Saipan), a brown hispine beetle, which breeds between leaves in the expanding bud, was found in infestations extremely destructive to the small coconut plantings of Rota and Saipan, especially near sea level, where leaves of most all palms were brown from the attacks. Damage by this species in the Carolines and by *Brontispa* sp. (possibly *B. mariana*) (Nukuoro, Ulithi, Woleai, Yap) was far less important, severe injury being observed on an occasional palm only. *Brontispa* sp. (possibly *B. chalybeipennis* Zacher) (Kusaie, Palau Is., Ponape; Ailinglapalap, Jaluit, Majuro), a blue species with habits similar to those of *B. mariana*, was destructive locally to coconuts in Ponape, slightly damaging in the Palaus, and sparse on Kusaie and the Marshalls.

Nasutitermes brevirostris (Oshima) (Termitidae) (Palau Is., Ponape, Truk, Ulithi, Woleai, Yap) covered tunnels were a common sight in the infested islands. The tunnels were often well embodied into trunk tissue and reached to the tops of the palms, where the insects fed on dead leaf stalks. This species caused some damage to palms.

Oryctes rhinoceros (L.) (Scarabeidae) (Palau Is.), the coconut rhinoceros beetle, was devastating coconuts on Koror around the centre of its apparent place of introduction and on the southern tip of Babelthuap. Thousands of decaying stumps and dead war-casualty palms were supplying most favourable breeding sites for the insect. It was first introduced probably in about 1942, and is now rapidly spreading.

Rhabdoscelus obscurus (Bdvl.) (see Corn, etc.) occasionally injured coconut somewhat by tunnelling in leaf stalk bases and in tissue surrounding freshly cut notches in trunks made by natives to facilitate climbing. On the Palaus, Ulithi, and Woleai considerable tunnelling attributed to this species, was noted in the mesodermal layer of trunks not mechanically injured. Some additional damage to notches in trunks was due to attacks by larvae of *Diocalandra frumenti* (F.) (Truk; Guam) and *Diocalandra* sp. (Palau Is., Ponape, and Ulithi).

Segestes unicolor Redt. (Tettigoniidae) (Palau Is.) was common on coconut leaves. The ragged leaf edges they caused, however, were not serious except in occasional spots.

Of at least 19 species of coccids found on coconuts, the following were the most important:

Aonidiella inornata McKenzie (see Citrus) was abundant on coconut in parts of the Marshalls, but sparse elsewhere.

Aspidiotus destructor (Sign. (Palau Is., Ponape, Truk, Yap; also Oleai (Takahashi 1939, p. 269); Guam, Saipan, Tinian), the coconut scale, was seldom found on coconut. A coccinellid predator, *Telsimia nitida* Chapin (Palau Is., Ponape, Truk; Guam, Saipan, Tinian; Kwajalein) generally accompanied the scale on other hosts.

Furcaspis oceanica Ldgr. (Hall Is., Kusaie, Palau Is., Ponape, Truk, Ulithi, Woleai, Yap; Guam, Saipan; Ailinglapalap, Jaluit, Kwajalein, Likiep, Majuro; also Wotje (Takahashi 1939, p. 270)), a red scale, was sparse on coconuts in the Carolines, but abundant in some localities on Guam, Saipan, and the Marshalls. It also occurred on *Nipa fructicans* and *Pandanus*.

Lepidosaphes esakii Takah. (tentative identification) (Kusaie, Nukuoro, Ponape, Woleai; Eniwetok, Kwajalein, Majuro; also Truk and Saipan (Takahashi 1939, p. 268, and 1941, p. 218)), normally infesting *Pandanus*, was abundant on coconut in some Marshall islets. *L. duponti* Green (Guam, Saipan) on leaf stalk bases and *L. mcgregori* Banks (Palau Is., Yap; Guam, Saipan, Tinian) on leaves, were of local importance. The last species was abundant on *Areca*.

Pseudococcus oceanicus Takah. (Coccidae) (Hall Is., Kapingamarangi, Kusaie, Nukuoro, Palau Is., Ponape, Truk, Woleai; Ailinglapalap, Jaluit, Likiep), a mealybug, was sometimes abundant on leaf-stalk bases of spreading buds and on an occasional base of a spadix. Eight other species of *Pseudococcus*, with more restricted distributions, were found in similar infestations or on leaves.

Spathe borers (family not yet identified) were common throughout the Carolines and Marshalls, but were not outstandingly significant. *Batrachedra* sp. (Cosmopterygidae) (Eniwetok) was damaging to male flowers, as were *Eobia* ? spp. (Oedemeridae) (Ailinglapalap, Jaluit) and *Glaucias* sp. (Pentatomidae) (Saipan).

Unidentified leaf-feeding insects included at least two species of tineid leaf tyers (Kusaie, Ponape, Nukuoro; Ailinglapalap, Jaluit, Majuro), one or more of which were important in some Ponapean localities. Two species of thrips, two of acridids, a derbid, a cixiid, and an aleyrodid with restricted distributions were of minor importance.

Coffee

Small coffee (*Coffea arabica*) plantings of little commercial value were encountered on Ponape, Guam, Rota, and Saipan.

Araecerus vieillardi (Montr.) (Anthribidae) (Truk; Guam) larvae were infesting about 20 per cent of the ripe berries of *Coffea liberica* in a Guam planting.

Stephanoderes hampei (Ferr.) (Scolytidae) (Ponape; Saipan) attacks to coffee berries were especially severe on Saipan, many immature berries and all ripe ones being infested. The Ponape infestation was of lesser importance.

Six scale insects were found on coffee, but were of minor importance, except *Ischnaspis longirostris* (Sign.) (Guam, Saipan; also Palau Is. (Takahashi 1936, p. 117), which was very abundant on leaves on Saipan.

Papaya

Papayas (*Carica papaya*) were seldom observed in Micronesia, although scattered plants were found on most of the islands and a few commercial plantings on the Marianas. Coccids, *Aonidiella comperei* McK. (Truk; Tinian; Ailinglapalap, Jaluit) and *Aspidiotus excisus* Green (Nukuoro; also Yap (Takahashi 1941, p. 220); Tinian) were occasionally observed in abundance on fruits, the first-named species occurring similarly on stalks. The oriental fruit fly, *Dacus dorsalis* Hendl., was of minor importance to ripe fruits on Saipan and Tinian.

Pineapple

Scattered plants and small patches of pineapples (*Ananus sativus*) were commonly found on most of the islands surveyed except in the Marshalls. The crop was little molested by insect pests, although the pineapple mealybug (*Pseudococcus brevipes* (Ckll.)) (Ponape, Truk; also Palau Is. and Yap (Takahashi 1941, p. 214); Guam, Rota, Saipan, Tinian) was common on them.

Pests of Vegetable Crops

Beans and Other Legumes

String beans (*Phaseolus vulgaris*) and Chinese asparagus beans (*Vigna* sp.) are extensively cultivated on Guam; wild crotolaria (*Crotolaria* spp.) is common throughout the high islands surveyed, and miscellaneous plantings of cowpeas (*Vigna sinensis*), pigeonpeas (*Cajanus cajun*), and wing beans (*Phophocarpus tetragonolobus*) were observed a few times on the Marianas.

Acrocercops sp. (Gracilariidae) (Yap; Guam, Saipan, Tinian) leaf-mining larval attacks were severe on cowpeas, string beans, Chinese asparagus beans, and *Vigna marina*, except in areas receiving aerial sprayings for mosquito control, where the pest was noticeably absent.

Anticarsia irrorata (F.) (Phalaenidae) (Truk, Woleai; Guam; Majuro) was found to have defoliated a field of cowpeas on Guam.

Aphis medicaginis Koch (Aphidae) Kusaie, Palau Is., Truk, Woleai; Guam, Rota, Saipan; Ailinglapalap, Eniwetok, Jaluit) was sometimes found in damaging numbers on Chinese asparagus beans, cowpeas, pigeonpeas, and *Vigna marina.*

Cryptophlebia carpophaga (Wlsm.) (Olethreutidae) (Guam, Rota, Saipan, Tinian), a pod boring species, was sometimes serious on string beans when grown within the vicinity of the wild hosts of *Cassia occidentalis* and *Pithecellobium dulce.*

Empoasca sp. (Guam) (Cicadellidae), a leafhopper was abundant on cowpeas.

Etiella zinckenella (Tr.) (Phycitidae) Palau Is., Ponape, Truk; Guam, Tinian), a pod borer, was found on beans and crotolaria, often abundant on the latter.

Lampides boeticus (L.) (Lycaenidae) (Palau Is., Truk, Yap; Guam, Saipan, Tinian), infested pods of crotolaria, pigeonpeas, and *Vigna* sp., sometimes abundantly.

Maruca testulalis (Geyer) (Pyraustidae) (Guam), a pod borer, was found occasionally on string beans, and sometimes in severe infestations on pigeonpeas in 1937-39.

Melanacanthus ferrugineus (Stal) (Coreidae) (Guam, Rota, Saipan, Tinian) was occasionally important to cowpeas and pigeon peas.

Nacoleia diemenalis (Guen.) (Pyraustidae) (Truk; Guam), a leaf roller, was often destructive to string beans. It also attacked wing beans, *Dolichos lablab*, *Indigofera hirsuta*, and *Vigna marina.*

Nezara viridula (L.) (see Rice) was common and sometimes abundant on crotolaria.

Phycitidae larvae (species?) (Saipan, Tinian) were destructive to leaves of pigeonpeas, groups of which they tied together for protection and feeding.

Beet

There were occasional plantings of beets (*Beta vulgaris*) on Guam and Saipan. They were damaged by *Hymenia recurvalis* (F.) (Pyraustidae), a leaf webber abundant on *Amaranthus.*

Crucifers

Few crucifers were observed in the survey. In 1937-39, however, cabbage (*Brassica oleracea capitata*) and mustard (*Brassica* sp.) were occasionally found in small plots on Guam during the cooler months of the year, while radishes (*Raphanus sativus*) and Chinese cabbage (*B. pekinensis*) were grown extensively during the same months.

Brevicoryne brassicae (L.) (Aphidae) (Guam) was occasionally abundant on Chinese cabbage. *Rhopalosiphum pseudobrassicae* (Davis) (Guam), another aphid, was often extremely abundant on radish.

Crocidolomia binotalis Zell. (Pyraustidae) (Guam), the cabbage moth, though occasionally destructive to cabbage and radish, was generally of little importance.

Hellula undalis (F.) (Pyraustidae) was damaging to cabbage, mustard, and radish, but was seldom very injurious.

Prodenia litura (F.) (see Corn, etc.) larvae were occasionally destructive to young cabbage heads.

Cucurbits

Cucumbers (*Cucumis sativus*), melons (*Cucumis melo*), pumpkins (*Cucurbita pepo*), squash (*Cucurbita* sp.), and watermelons (*Citrullus vulgaris*), are commonly grown in the Marianas. Elsewhere in Micronesia, however, cucurbits were little encountered, except occasional untended vines, probably of *Luffa* spp., throughout most of the islands.

Aphis gossypii Glov. (see Cotton) was frequently abundant on melons.

Aulacophora (*Ortholaca*) sp. (Chrysomelidae) (Palau Is.) adults, feeding gregariously, were abundant on leaves of *Luffa* sp. *Raphidopalpa femoralis* Mots. (Palau Is., Yap), a second leaf beetle, was abundant on leaves of scattered watermelon plants and on *Luffa* sp., an indication that it was capable of being very destructive.

Dacus cucurbitae Coq. (Tephritidae) (Guam, Saipan, Tinian), the melon fly, was found to be destructive to a few cucurbits but was either scarce or apparently absent from many fields.

Diaphania indica (Saund.) (Pyraustidae) (Truk; Guam, Rota, Saipan, Tinian; also "Mandates" (Esaki 1940, p. 412)), a leaf-folding species, was common on cucurbits, but no serious damage was observed except on a few isolated plants.

Leptoglossus australis (F.) (Coreidae) (Palau Is., Truk, Ulithi; Guam, Rota, Saipan, Tinian) was often abundant on *Passiflora foetida*, but was seldom found on cucurbits and beans which it is known to damage at times.

Eggplant, Pepper, and Tomato

Solanaceous vegetables—eggplant (*Solanum melongena*), pepper (*Capsicum*), and tomato (*Lycopersicon esculentum*)—were commonly encountered in the Marianas, but were rarely observed in the Carolines and Marshalls.

Aphis gossypii Glov. (see Cotton) was taken on pepper a few times, but not in important infestations. *Myzus persicae* (Sulz.) (Saipan), another aphid, was of slight importance to eggplant.

Chrysodeixis (*Plusia*) sp. (Phalaenidae) (Guam) larvae were damaging to leaves of eggplant.

Cyrtopeltis tenuis Reut. (see Tobacco) was usually present on tomato. Its attacks on this vegetable were reported severe at times.

Heliothis sp. (Tinian) (Phalaenidae) larvae lightly damaged tomato fruit on Guam and Tinian.

Leptocentrus sp. (Membracidae) (Guam, Rota, Saipan) was taken on eggplant in minor infestations.

Nezara viridula (L.) (see Rice), was occasionally found on eggplant.

Saissetia sp. (Coccidae) (Guam) was observed on eggplant, to which it was reported injurious at times.

Besides the above, two tettigoniids—*Conocephalus longipennis* (Haan) (see Rice) and *Phaneroptera furcifera* Stal (Rota, Saipan, Tinian)—were frequently found on pepper and eggplant.

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CONTROL OF INSECT PESTS

CONTROL OF LIVESTOCK INSECTS IN BRITISH COLUMBIA BY THE NEW ORGANIC INSECTICIDES[1]

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IT would be unwise at this date to accept as final the promising results of some of the newer livestock insecticides. Spectacular and encouraging as they may appear, there still remain the delicate problems of studying the effects of these chemicals on the hosts, whether plant or animal, and the effects that consumption of treated vegetables and meat may have upon human beings. If and when it becomes established that vertebrate life need not be endangered or contaminated by the use of special preparations of the chemicals, then there is every reason to look forward to a new era of livestock insect control. Indeed, the number of specific insecticides appears to be ever expanding, and it is not improbable that further improvements and discoveries in the chemical field will yet yield materials to attack the few remaining resistant parasites. It is hoped that the following discussions of some of the uses of the newer insecticides on livestock pests in British Columbia will contribute to the picture as it now stands.

The paralysis tick, *Dermacentor andersoni* Stiles, is the most serious pest species of ticks recorded for Western Canada. Purely a dry belt tick, it has taken a toll of up to a hundred head of cattle during a single outbreak in British Columbia, while every year there are minor losses involving small numbers of sheep or cattle. Though engorging females may be readily killed by swabbing them with creosote or pine tar, a treatment has been needed that will prevent them from attaching to livestock. DDT sprays have shown little promise in this respect. Benzene hexachloride, on the other hand, appears to be the long-sought acaricide, not only being lethal to engorging ticks but also offering protection from ticks for periods up to three weeks. This prolonged protection is highly desirable since the tick season in British Columbia lasts for four to six weeks, and animals are turned upon tick infested rangeland as early in this period as weather permits. Therefore, it is advantageous to approach as heavy a dose of the repellent as an animal can safely tolerate. Keeping this borderline in mind, it appears from experiments conducted at this laboratory that 0·5 lb. of 50 per cent wettable benzene hexachloride (7 per cent gamma isomer content) is harmless when applied as an aqueous suspension to the coat of a cow, and that the same material applied to the head, neck and shoulders at the rate of one ounce per imperial quart of water per animal (1·5 lb. gamma isomer per 100 gal. water) offers tick protection up to four weeks under normal spring weather conditions. Observations to determine what strengths were lethal to ticks already engorging revealed that dilutions of the gamma isomer as great as 0·023 lb. per 100 gallons of water were lethal to females that had been feeding for only one day. The greatest dilution of the gamma isomer found lethal to ticks that had been feeding for three days was 0·093 lb. per 100 gallons, while after five days' feeding, nothing less than 0·187 lb. per 100 gallons gave a complete kill. Ticks that had fed and had dropped from their hosts were resistant to gamma isomer at the rate of 0·375 lb., although this and the previous dilution did prevent them from ovipositing. Those subjected to greater dilutions laid eggs which produced healthy larvae.

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[1] Contribution No. 2579, Division of Entomology, Science Service, Department of Agriculture, Canada.

In the field, benzene hexachloride was incorporated with a standard derris warble wash and applied at the above rate of one ounce per animal, at a pressure of 400 lb., to the heads and backs of 250 heifers, cows and calves. Examined eight days after treatment, these cattle bore only dead, unattached ticks in their coats. With the exception of five small calves, which became paralysed by ticks at the tenth day, and which on account of their size may not have received proper coverage, all these animals passed through the tick season without mishap.

This possibility of combining the tick and warble treatments is being looked upon with considerable interest by ranchers concerned with both pests, since the elimination of an extra round-up of stock would represent a great saving of labour and time. Such a dual treatment, however, should not be delayed beyond the peak emergence of warble grubs, and for this reason would be earlier than necessary for ticks. Here then are an additional demand on the lasting powers of the acaricide and a call for further studies on factors determining its stability under spring weather conditions. The shortness of the tick season is of considerable disadvantage to the research worker in this respect, for all studies must be conducted during the normal activity of the adults. Since the tick repellent need be applied only at the site of attachment of this species, namely along the shoulders, neck, and head, while the warble wash is power sprayed over the back, it may be more economical to apply the materials separately as the animals pass through a chute.

Cattle lice, though not a serious problem in British Columbia, do occur in large numbers on particular individuals within a herd. DDT as a one per cent spray or dust has been proven by various workers to be effective in controlling this pest.

Approaching the control from a newer angle, some observations have been made with regard to the effect on parasites of oral doses of benzene hexachloride to the host. These tests have been patterned after studies conducted in South Africa by de Meillon (1946). Two 400-500 lb. heifers, heavily infested with *Haematopinus eurysternus* (Nitzsch), were each given an oral dose of 650 mg. pure gamma isomer of benzene hexachloride in water. Within two days the infestation had completely vanished. At the end of two weeks the occasional sucking louse was again noted, these presumably having hatched after the treatment. A colony of biting lice, *Bovicola bovis* (L.), were unaffected, a fact which is readily understood if the gammexane is distributed by the blood stream. No apparent harm was done to the animals, one of which received a second similar treatment one month later. In the latter instance the two treatments were approximately five weeks and one week prior to warble grub emergence from the animal's body, and it is to be noted that all the grubs matured, dropped, pupated, and emerged normally.

Although de Meillon found that doses of "gammexane" similar to the above, when given to rabbits (at the rate of 50 mg. per 1730 gm. body wt.) were largely lethal to bedbugs (*Cimex lectularius* L.), mosquitoes (*Aedes aegypti* (L.)) and ticks (*Ornithodoros moubata* (Murray)), our tests with sheep keds (*Melophagus ovinus* L.), wood ticks (*Dermacentor andersoni* Stiles) and chicken mites (*Dermanyssus gallinae* L.) do not point conclusively in this direction. Oral doses in a sheep, up to 2 gm. per dose and totalling 6 gm., failed to kill any of the keds. The sheep appeared to be unharmed, and the mutton was untainted. The sheep would voluntarily take about 1·5 gm. of the powdered gammexane in oats, but after that developed a dislike for the meal. Most doses were given as a drench. Tests on sheep and mice, infested with *D. andersoni* adults and larvae, respectively, were not conclusive, but suggested that the parasites might be affected by oral doses of benzene hexachloride to the host. Chicken mites, on the other hand, were unaffected on two occasions by a series of 200 mg. doses that finally killed the chickens.

Keds, having received in British Columbia a lesser degree of attention than some of the more important livestock pests, still await a satisfactory method of control. On account of the practice at the western ranches of summering the sheep high in alpine country, it is not practical to undertake fall treatment until late in the year. At that time cold weather renders dipping unwise, and therefore it would appear more advisable to use a power driven dust or spray. The latter has been shown to be successful in Idaho, United States, where it has been possible to secure a sufficient penetration into the fleeces of fast moving sheep in a chute. Our tests have failed in this respect on account of inadequate penetration of the wool. However, it was noted that the use of 0·5 lb. of 50 per cent benzene hexachloride (gamma isomer content 7 per cent) per 5 gallons of water produced a delayed kill, due possibly to the fact that the keds subsequently came to the surface of the fleece, where they contacted the insecticide. Small-scale tests showed this chemical to be more lethal to this pest than similar concentrations of DDT. However, the Idaho workers found that a 0·4 per cent suspension of DDT effectively controlled the pest, as has the Dominion Livestock Insect Laboratory at Lethbridge, Alta., the latter using a crowding pen and an overhead spray. On the whole, it would appear that keds are susceptible to most insecticides, and that it is the mechanical problem of application that requires attention.

Warble grubs are still most effectively controlled with the standard derris mixture of approximately 5 lb. of derris (5 per cent rotenone content) per 80 gallons of water. This is applied by hand, or, as practised by ranchers, by power sprayers with pressures of 400 lb. DDT and BHC are apparently of little value in combating the grubs. A 2 per cent suspension of DDT, applied liberally to the coats and legs of cattle immediately prior to warble fly emergence did not protect them from oviposition and subsequent grub infestation in tests conducted at the Kamloops laboratory. This treatment also failed in the United States, where emulsions and solutions of DDT up to a strength of 5 per cent were applied.

The use of DDT against mosquitoes is a different matter, and, as is well known, the addition of small amounts to oil or water sprays produces a very superior larvicide. Application of 0·1 lb. of DDT per acre in an oil solution or an aqueous emulsion, whether applied by ground equipment or plane, effects a satisfactory control under most conditions. As an adulticide, DDT has been effectively applied by plane at the rate of 1 lb. per acre as a spray, but not as a dust.

Even more spectacular is the effect of this chemical on blackfly (Simuliidae) larvae. Tests made at Kamloops indicate that DDT emulsions, at the rate of one part DDT to twenty million parts water per hour's treatment, were lethal to the larvae of this pest. With this larvicide, blackfly-infested mountain streams have been cleared out for several miles with a single treatment.

In this brief paper no attempt has been made to discuss the large amount of work done outside of British Columbia on the effect of modern insecticides on livestock pests. The topic is so vast that it is indeed difficult for a small research staff even to keep up with the literature on the formidable array of new materials and new formulations, let alone test them. Many of the problems referred to above call for continued studies in larger and more practical proportions. However, the results to date have been encouraging and stimulating.

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CHEMICAL CONTROL OF WIREWORMS IN WESTERN CANADA[1]

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THE impact of the newer insecticides probably has been greater in the control of wireworms than in any other group of insects.

Prior to 1945 the status of wireworm control in Western Canada could have been summed up as follows: "Soil insecticides are either ineffective or, with the partial exception of naphthalene, far too costly or otherwise impractical for use even with truck crops. Seed treatments are of no direct value and, in fact, may even be said to offer little or no prospect of success. The ravages of the pest to wheat and other cereals grown under dry farming conditions may be kept down fairly well, however, by cultural methods (3) making most advantageous use of the summer fallow year and of seeding methods for the subsequent crop, which is always that most subject to damage. On the other hand cultural methods are inadequate for the protection of vegetable crops, especially in irrigated land in British Columbia for which no effective practical remedy against wireworms exists." These were the general conclusions based on investigations in the Prairie Provinces initiated in 1922, in the course of which all the seed treatments available had been tested in field and laboratory. Considerable attention had also been given to soil fumigants such as carbon disulphide, cyanide and naphthalene.

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[1] Contribution No. 2586, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.

The current conclusions, based on recent work, afford a sharp contrast to the above: Soil treatment with insecticides now affords economical and highly effective control of wireworms in truck crops, and is being increasingly used by practical growers. Seed treatments have been found to be very effective for the protection of cereal crops from wireworms, and show much promise of providing a practical solution for this problem, in conjunction with the tillage measures previously established.

The present paper is limited to an outline of the wireworm problems in the Prairie Provinces and British Columbia and a summary discussion of the results of recent work in these two regions. The detailed data, mostly unpublished, from these investigations are not included.

The Wireworm Problem

In any problem of insect control a primary consideration is the cost of treatment relative to the crop saving which it affords. On this practical basis, the wireworm problem in Western Canada is divisible into two fairly clear-cut major aspects: (1) Control in wheat and other cereal crops which have a relatively low value per acre; (2) control in crops having a considerably higher unit value, such as potatoes, other vegetables, gladiolus and strawberries, which for convenience, will be listed here loosely as "truck crops". The wide difference in wireworm pest species in the two regions is of secondary importance for the present discussion, except insofar as it determines the effectiveness of the various chemicals.

The wireworm problem in cereal crops involves an immense acreage chiefly in the Prairie Provinces. In Saskatchewan, for example, the loss of field crops in 1947 was estimated (1) to be 15 million dollars. The average annual loss in that Province is between three and four per cent of the potential crop value, and probably occurs at about the same rate in Alberta and Manitoba. In individual fields, destruction of one-fourth or more of the crop occurs rather frequently. The effect is particularly serious because it chiefly affects the most important cash crop, wheat planted on summerfallow.

The wireworm problem in truck crops involves a relatively small acreage but the monetary loss is very considerable. This is especially true in British Columbia where a great variety of highly valuable commercial crops are affected. In the production of these crops heavy wireworm infestations, especially in irrigated land, are often a critical or limiting factor. In the Prairie Provinces wireworms are a serious problem in home gardens, potato fields, and to a lesser extent in irrigated vegetable cropland; but the problem there is not of as great economic importance since this type of crop is less frequently the main source of income.

The work with chemicals in Western Canada so far has dealt mainly with the species of chief importance in the two regions, the Prairie grain wireworm, *Ctenicera aeripennis destructor* (Brown) on the Prairie Provinces, and the Pacific Coast wireworm, *Limonius canus* Lec. in British Columbia. More limited observations have been made on the Prairies with *Hypolithus nocturnus* Esch., commonly associated with *C. destructor* in heavy soil in low moister places; and in British Columbia, with the Western field wireworm, *L. infuscatus* Mots., the Puget Sound wireworm, *C. aeripennis aeripennis* (Kby.), *C. lobata* (Esch.) and a species of *Agriotes* possibly *sparsus* Lec.

Some differences have appeared in the relative effectiveness of the different chemicals upon *C. destructor* and *L. canus,* but these may be due in part to differences of environment rather than solely of species reaction. *L. canus* occurs as a pest only in sandy or sandy loam soils, in irrigated land and in bottom land of the wetter coastal area of British Columbia. *C. destructor* may be abundant in any type of soil, although rarely in the heavy clays on very sandy soils. A serious infestation of either species, once established, continues as a permanent problem unless controlled, although natural variations in abundance occur. *L. canus* increases under intensive truck farming, but the numbers drop somewhat when alfalfa is used extensively in the rotation. *C. destructor* maintains itself under dry land grain farming, reaching a high population level when wheat is used too frequently in that rotation as well as when the land is left in grass for some years. For larval development, *C. destructor* requires five or more years, *L. canus* mainly three years in British Columbia. *L. canus* adults spread freely by flying; but infestations of *C. destructor* spread very slowly because the adults apparently do not fly.

Chemical Control in Cereal Crops

Even though wireworms constitute a major problem in dry-land wheat production, the practical applicability of chemical control is restricted, not only by the low and uncertain profit but also by the fact that the pest can there be kept fairly well in check, without added cost, by cultural measures, although they are slow in reducing wireworm numbers. As a consequence, seed treatments, because they are relatively less costly than soil treatments, hold the greatest promise of widespread practical usefulness now that effective materials have been developed.

Seed Treatments

Seed treatments require only a small amount of material at relatively low cost per acre. However, for widespread practical use in grain fields the cost probably needs to be further reduced from the present tentative price of about 3 dollars per acre. The insecticide is applied to the seed immediately before seeding by the same means as are already in widespread use by farmers in treating seed with organic mercury dusts for the control of smut; in fact, the two treatments can be combined. No other special treatment is needed for wireworm control. The wireworms are attracted to the seed and are either immobilized or killed by the chemical before they can injure the seed or seedlings. A single treatment, at suitable rates, is capable of reducing all but the very heaviest infestations to numbers that will cause little or no trouble for five years or more. Complete control of an infestation in one season is not likely to be obtained however, from even the heaviest feasible rate of application. In prairie agriculture, the principal place for the seed treatment is for the protection of the crop immediately following summerfallow. Once wireworms have been reduced to non-economic numbers, cultural methods can be employed to prevent any further recurrence of economic infestations.

Benzene Hexachloride. Treatment of seed with dressings containing 20 per cent to 50 per cent purified gamma benzene hexachloride, used either alone or in combination with organic mercury dust,[7] at a rate of one to two ounces of gamma isomer per bushel of wheat seeded at 75-90 pounds per acre, has given the most consistent results in extensive plot tests and in field demonstrations. The one-half, one- and two-ounce rates produced an average reduction in the wireworm population of 50, 75 and 80 per cent respectively. At the four-ounce rate, however, the average reduction has been only 70 per cent. The reason for this reduction in effectiveness from the two-ounce rate is not clear. All rates have reduced damage to the crop by about 90 per cent, an unexpectedly high degree of protection. The best plant stands were obtained with the one-ounce rate. The use of more than two ounces per bushel of the gamma isomer, especially in combination with the mercuric dust, has tended to reduce germination and delay early growth. The half-ounce rate, on the other hand, has appeared to stimulate plant growth in the early stages. While giving almost as good protection as higher rates, the half-ounce rate has not given as great a reduction in wireworm numbers as is considered desirable. For the present, therefore, considering cost and the degree of control, the one-ounce rate is considered the most satisfactory rate of application.

These treatments had no effect on the flavour or quality of the harvested grain. Yield increases have ranged from none to about 40 per cent under the rather unfavourable dry weather conditions prevailing during these tests.

Benzene hexachloride seed treatments appear to be equally effective in the principal soil types encountered in the Prairie Provinces and under all conditions of moisture and temperature normally found at the time of seeding.

Other Seed Treatments. Chlordane, in experiments as a seed treatment on wheat, appears much less promising than benzene hexachloride, being less effective against wireworms and more harmful to germination as well as delaying maturity. At two to four ounces of technical material per bushel of wheat, however, chlordane has shown considerable, though extremely variable, effectiveness in reducing both wireworm numbers and crop damage. Parathion, in laboratory experiments as a seed dressing, at rates of one to four ounces of the actual ingredient per bushel, seems fully equal to gamma benzene hexachloride in reducing numbers of, and damage by, wireworms. It has less harmful effect on germination and seedling growth, and possibly even stimulates growth. DDT as a seed treatment on wheat, in limited studies, has neither prevented damage nor reduced wireworm population sufficiently to be considered promising in this area. Other materials that have proved ineffective or damaging to the seed, in recent or earlier work with seed dressings, include: sulphur, nicotine sulphate, rotenone, turpentine, kerosene, mustard oil, and arsenicals.

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[7] Such as Canadian Industries Limited "Benesan 21", containing 20 per cent gamma isomer and 1 per cent organic mercury for smut control.

Soil Treatments

In work on the Prairies during the four seasons 1945-48, the application of benzene hexachloride to the surface of the soil and immediately worked in to a depth of four inches with a plough or one-way disc, at rates of one-third to one and one-quarter pounds gamma isomer per acre, has cut in half the wireworm damage to wheat seeded at the time of application and had apparently no adverse effect on growth, development or flavour of the wheat. However, when benzene hexachloride was concentrated in the drill row at time of seeding, it reduced germination and damaged seedlings. Soil treatments of chlordane at effective rates delayed maturation of wheat, especially when concentrated in the drill row with the seed. Other points in connection with soil treatments will appear in the next section.

CHEMICAL CONTROL IN TRUCK CROPS

Economic factors, as already outlined, give practical possibilities to a considerable number of effective materials, including soil treatment with liquid or dust materials, as well as seed dressings. With root crops the question of the tainting effect of various chemicals assumes dominant importance, but in the case of other crops this factor has not been of much significance, though the effect of the chemicals on plant growth and yields may be of importance.

In Western Canada, the wireworm problem in truck crops has not the acreage or severity to warrant the use of expensive equipment for application of chemicals, nor custom treatments of the soil. Simple practical means of application, therefore, are essential. Growers tend to show a considerable preference for dust treatment of the soil instead of the use of liquids. However, the development of simple applicators for use on the plough, e.g. King and Andison, 1947, (4) has made it quite feasible for any grower to use liquid fumigants where ploughing is a normal practice. Moreover, where growers have once had experience with the use of liquid fumigants the objection, often amounting to prejudice, against this type of application is reduced or eliminated. It may be mentioned also that application of material in dust form also calls for some special equipment, and often requires a greater amount of additional tillage than liquids. No practical use has yet been made in this area of application of chemicals to the soil in spray form.

Liquid Fumigants

Ethylene dibromide at the rate of one and one-half imperial gallons of the toxicant per acre, has proved very effective under a wide variety of conditions in British Columbia, both in experimental work and in practical use by growers. Destruction of *L. canus* has consistently approached 100 per cent. Adequate controls have been reported by growers at rates as low as one gallon of the toxicant per acre. The temperature factor has been found less important than at first expected, but it is evident that treatments should be avoided when the soil is likely to be "cold" for a lengthy period after application, as in the late fall. The material is also ineffective when applied in very wet soil. In limited work on the Prairies, ethylene dibromide has not been equally effective against *C. destructor*, apparently requiring somewhat higher rates of application which increase the cost and render this material less promising there. Ethylene dibromide causes no taint to the crop. The effect on both crop and soil appears to be beneficial even apart from wireworm control.

Dichloropropane-dichloropropene mixture has proved fairly effective in British Columbia and the Prairies, but the present cost, which runs several times higher than for ethylene dibromide, precludes its present use on a large scale. This is true also of methyl bromide, carbon disulphide and chloropicrin.

Dust Treatment of the Soil

This work has dealt chiefly with benzene hexachloride which, where tainting is of no importance or can be eliminated, is perhaps the most promising of the new chemicals. Other materials that may show a practical usefulness are DDT, parathion and chlordane. In preliminary trials in British Columbia, chlorinated camphene has not given adequate control.

Soil treatments of benzene hexachloride have given excellent control of all the species referred to above. On the Prairies, for example, mortality of *C. destructor* averaged about 80 per cent using benzene hexachloride at one-half pound gamma isomer per acre, and was almost as good at one-third pound per acre, and about 95 per cent with one and one-quarter pounds per acre. These are approximate averages from tests conducted during four years, under wide variations of moisture, temperature, and soil texture, where the benzene hexachloride was broadcast over the surface of the soil and immediately worked in to a depth of four inches. Similar mortality has been secured in British Columbia, particularly with *L. canus*. In both areas, potatoes grown in soil treated at the time of planting, or the previous fall, have been protected from serious damage. However, when crude benzene hexachloride has been used, the new tubers have been seriously tainted, even by the lower effective rates of application and by treatments made in the fall. Tainting sufficient to cause commercial rejection has also occurred even in the second season in most instances. Recent work on the Prairies with purified gamma benzene hexachloride not only has given promising controls but indicates that tainting is greatly reduced. Except for such material, benzene hexachloride should not be used in land where potatoes are to be grown within at least two seasons after application. Even with the purified material the dosage should not exceed one-half pound gamma per acre when applied in the spring, and treatment the preceding year appears to be required to avoid all trace of taint.

Soil treatment with chlordane has given variable results with *C. destructor*. About ten times as much chlordane as gamma benzene hexachloride is required to effect the same degree of control. In irrigated land in British Columbia results have been highly variable, very high mortality having been secured in some instances from soil applications at rates as low as one-half pound actual chlordane per acre and in other instances less than 50 per cent control from applications at rates eight to ten times greater. There is clear indication that the moisture factor at time of application, or soon after, may be of critical importance. Slight tainting of potatoes and carrots has been indicated in both areas, although probably not sufficient to be serious commercially. Parathion has been tested only in preliminary laboratory trials on the Prairies and limited field tests in British Columbia. As a soil treatment it is faster acting and apparently fully as effective as gamma benzene hexachloride, but its residual effects may be much shorter. Because of its high toxicity to man and warm blooded animals and because it may also poison plants as well, parathion will have to be tested much more extensively before its place as a soil treatment for wireworm control is determined.

The position of DDT as a soil treatment is still uncertain in Western Canada. Spring treatments at the rate of twelve and one-half pounds actual DDT per acre have given no protection whatever to potatoes in British Columbia, and only slight protection when applied the preceding fall. On the Prairies only slight reduction in either damage by, or population of, *C. destructor* has been secured in the year of treatment by application of twenty pounds per acre; while even at one hundred pounds per acre control has not been equal to one-half pound gamma benzene hexachloride per acre (2). *C. destructor*, possibly because of its larger size and slower development, appears to be more resistant than *L. canus* to DDT. In British Columbia, however, it is considered probable that the residual effect of DDT will give this material a definite place in the control of species of *Limonius*, although perhaps not equal to that it has taken in more southerly areas in the western United States (5).

Crude naphthalene applied at 700-900 pounds per acre in midsummer effectively controls wireworms on the Prairies, and no doubt in British Columbia also. The cost of the material and the laborious and exacting method of application make its use prohibitive in grain fields and even deters its use in gardens. Spring or fall applications have not given satisfactory control, and rather serious phytotoxic effects on cereals and vegetables have resulted from spring application.

Seed Dressings

Treatment of potato seed pieces with gamma benzene hexachloride has given satisfactory control of wireworms and protection of the subsequent crop, but injures germination and root growth to an extent that depresses not only the gross but also the net yield. These have been the results both in British Columbia and the Prairies. On the other hand, gladiolus corms[3] in British Columbia, treated with benzene hexachloride dust containing 0·25 or 0·5 per cent gamma isomer, or the latter sprinkled along the row just before planting the corms, have received good protection from wireworms and no apparent injury to plant growth.

In gardens on the Prairies, the benzene hexachloride seed treatment method, employing cereals as the carrier and applied about three weeks before the garden is planted, has shown marked promise as a method of controlling wireworm infestations, of reducing damage, and of eliminating the danger of tainting susceptible root crops grown during the year of application. To eliminate damage completely this treatment may have to be used in more than one year. If cereals or summerfallow are used in the garden rotation, the treatment can be made in those years.

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[3] Joint work with H. Andison.

CONCLUSIONS

The recent development and introduction of new insecticides of great effectiveness against wireworms provide, for the first time in Western Canada, efficient and practical chemical means of control of these pests. This conclusion is based on investigations over a four-year period in which, following earlier work, ten materials and various methods of application were tested in laboratory and field.

Benzene hexachloride applied as a seed dressing to wheat provides the first practical chemical method of control of the serious wireworm problem in grain fields of the Prairie Provinces, although reasonably satisfactory cultural methods have been in use for many years. The seed treatment not only reduces wireworm numbers quickly but also protects the crop from serious damage in the year of application. It appears to be equally effective in all principal soil types and under all conditions of soil temperature and moisture normally found at the time of seeding. Its present cost of about 3 dollars per acre may still be too high for its general use by farmers, even though this cost is reasonable when it is realized that it should be spread over a period of five years or longer. Soil treatments, even when effective, are still considered to be impractical for use in grain fields.

In land used for truck crops, where formerly neither cultural nor chemical measures gave effective crop protection, several insecticides now provide practical control. Ethylene dibromide has proved outstanding in its effectiveness and general usefulness in British Columbia. Crude benzene hexachloride dust applied to the soil surface and immediately worked in effectively and economically controls all species of wireworms in Western Canada, but its use is limited because of its tainting effect on root crops, especially potatoes.

DDT, chlordane, purified gamma benzene hexachloride, and parathion are promising materials, but require further investigation to determine their practical value in wireworm control in Western Canada.

Dichloropropane-dichloropropene mixture, methyl bromide, chloropicrin, naphthalene, carbon bisulphide, cyanides, and chlorinated camphene are, for various reasons, impractical in Western Canada.

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DEVELOPMENT OF CONCENTRATE ORCHARD SPRAYERS IN CANADA[1]

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Introduction

A project on the development of high-speed orchard spraying equipment was initiated in 1946 at Summerland, British Columbia by the Division of Entomology, Science Service, Dominion Department of Agriculture. Work of 1946 and 1947 has been discussed in a previous paper (1). In the course of operations it became apparent that airborne equipment, while exceedingly rapid in action, did not apply dusts or sprays as efficiently as the better types of ground-borne equipment. On the other hand, the most effective ground-borne high-speed sprayers were expensive and cumbersome and their operation required heavy tractors. Orchard dusters were obviously less effective than sprayers apart from the fact that dust clouds are hard to control and therefore, potentially dangerous. Yet dusters have some very desirable features: they are light, easily manoeuvreable, rapid in operation, and relatively inexpensive. Clearly, an orchard sprayer with such characteristics would be a most welcome piece of equipment for Canadian fruitgrowers, the great majority of whom use light tractors in operating orchards too small to justify heavy or expensive spray equipment.

The Okanagan Experimental Sprayer

During the winter of 1947-48 the Defence Research Board of Canada built at their Suffield, Alberta, shops an experimental orchard sprayer designed on the lines just indicated. This machine, known as the Okanagan experimental sprayer, was the outcome of suggestions and financial support provided by the Fruit Branch, British Columbia Department of Agriculture and by the Division of Entomology, Science Service, Dominion Department of Agriculture.

The experimental machine was built with these requirements in mind: (1) light weight so that it might be hauled at very low speed by a light tractor (at such speed the tractor engine develops considerably less than its rated horsepower), (2) low centre of gravity to give stability on hillsides, (3) minimum overall height to enable passage beneath fruit trees, (4) a high velocity airstream to carry finely divided concentrated spray mixtures, (5) a "fishtail" air nozzle designed to operate not between rows but underneath the outer branches of the trees, (6) delivery of air at an angle of 90 degrees to line of travel, (7) a chassis on four staggered airwheels to provide minimum draft and cause minimum soil compaction, (8) a small spray tank, (9) a small hydraulic pump capable of delivering three to four imperial gallons per minute at a pressure of 300 p.s.i., (10) a light motor to power both the air turbine and the hydraulic pump, (11) suitable, if necessary, for operation by the tractor driver alone, and (12) capable of spraying 2 acres of fruit trees per hour.

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[1] Contribution No. 2585, Division of Entomology, and Contribution No. 167, Division of Chemistry, Science Service, Department of Agriculture, Ottawa, Canada.

Prior to construction of this machine a light steam aerosol generator[2] had made its appearance in the orchards of the Western United States and British Columbia. This equipment was new in theory and in mode of operation. A season's trials with it indicated that, under calm atmospheric conditions, it was capable of doing good work at high speed. Unfortunately, in some orchard areas the required air conditions were rare during the day and this necessitated night operations. It was concluded that the steam aerosol generator with its unusual capacity to reduce spray liquids to droplets of varying size at the turn of a thermoregulator, would probably be improved as an orchard sprayer if equipped with a suitable blower. The insecticidal fog that it produced would then be impelled both by a high velocity steam jet and by an independently moving airstream. Accordingly, when finally assembled the Okanagan experimental sprayer included not only the features necessary to meet the requirements already enumerated but a steam aerosol generator as well. The steam unit was so integrated with the hydraulic one that its insecticide tank supplied spray liquid either to two steam nozzles mounted on one side of the outer edge of the fishtail vent or to a bank of ten hydraulic nozzles mounted on the other side. At the turn of a valve the experimental sprayer could be converted from steam-airblast to hydraulic pressure-airblast operation. Furthermore, the steam unit could be operated as originally designed, without an airblast; it could also utilize either its own low-presure, variable-capacity pump or the independently powered, high-pressure pump of the hydraulic unit.

The Okanagan experimental sprayer, with insecticide and water tanks filled, weighs approximately one and one-half tons, but since it embodies two separate spraying systems that is not considered excessive. Both its high velocity, low volume air turbine and its hydraulic pump are powered by an air-cooled 20 horsepower gasoline engine; the pump is equipped with a clutch. One of the unusual components of the experimental sprayer is its "fishtail" air nozzle. The lower end of this device projects approximately two feet outward from the frame of the machine. Since the outer edge of the nozzle is inclined at an angle of 45 degrees to the vertical and is 4 feet long, the upper end is carried back within the area of the frame. The opening or vent of the nozzle is 48 inches long and 2 inches wide. In order to regulate air velocity along the length of the opening, two adjustable air deflectors are set well back within the air passage. When in operation the top end of the "fishtail" is carried along just beneath the periphery of the tree, thus the lower end is somewhat beneath the tree. Consequently, the airstream emerging in close proximity to the lower branches and being directed upward through the tree as well as horizontally, exerts maximum leaf movement and coverage with minimum power.

COMMERCIAL CONCENTRATE SPRAYERS

A commercial high-speed blower unit[3] capable of using spray concentrates and designed to convert the conventional mobile sprayer into an "automatic" machine was provided for spraying trials in 1948. This unit consisted of a blower powered by a water-cooled 20-horsepower motor together with appropriate air dispersing vents, spray liquid strainers and shut off valves; it weighed approximately 1900 pounds. Spray material from a conventional mobile hydraulic sprayer was piped back to special nozzles inserted along the mid-line of each air vent. Operating pressure was 400-600 p.s.i. and for all except one experiment, output was so regulated by nozzle change that approximately one-fifth the conventional amount of spray mixture was applied; consequently the concentration of spray mixture was increased five times. The trailer-blower sprayed to both sides simultaneously; it was used to apply dormant as well as summer spray mixtures.

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[2] "Beskil Aerosol Generator", Besler Engineering Corp., Emeryville, Calif., U.S.A.

[3] "Air-King" trailer-blower, Hardie Mfg. Co., Portland, Ore., U.S.A.

After successful trials of the Okanagan experimental sprayer had demonstrated the feasibility of using a blower unit in conjunction with the steam aerosol generator, the manufacturers of the steam machine undertook to develop a light blower for direct attachment to it. This blower was received late in the season but in time for a few trials against the pear psylla, *Psylla pyricola* Foerst. Subsequently the manufacturers developed and forwarded a second blower but its performance has not yet been assessed in field trials.

The hydraulic unit of the experimental sprayer attracted the attention of a local firm which had made a number of its parts. In the summer of 1948 this company[1] began construction of a hydraulic-air spray concentrate machine designed directly from the experimental equipment. The first unit of this type, known as the "Okanagan Turbo-Mist Sprayer", was released to the Summerland Laboratory for trials in the fall of 1948 and, like the modified steam machine, its performance was assessed only against the pear psylla.

Spray Deposits in Experimental Orchards

Not until summer spraying was under way was the performance of the Okanagan experimental sprayer brought to what was considered a state of reasonable efficiency; on the other hand, the "Air-King" trailer-blower unit was operated with apparent success in dormant applications. Nevertheless, in the course of the season's work, the Okanagan experimental machine was used on many experimental plots, with a minimum size of about one-fourth acre, in 23 different orchards. Aside from nozzle plugging, a difficulty eventually overcome, it gave little mechanical trouble in applying spray mixtures of 10 to 20 times conventional concentration and of such varying materials as lime sulphur, lime sulphur-dormant oil, elemental sulphur, ferric dimethyl dithiocarbamate, DDT, DDT-monoethanolamine dinitrocyclohexylphenolate, benzene hexachloride-summer oil, chlorinated camphene-summer oil, parathion wettable powders (various formulations) and parathion liquid concentrates (two formulations).

The trailer-blower unit was used in application of the standard British Columbia dormant spray mixture (lime sulphur-dormant oil) at conventional and five times conventional concentration in two orchards, both of which consisted of large apple trees up to 25 feet high. It was attached to a truck-mounted hydraulic sprayer operating at 550 p.s.i. and delivering approximately 12 imperial gallons per minute. In these trials the same truck-mounted sprayer serviced the hand spraying which, incidentally, was done with more than ordinary thoroughness.[5] Oil deposits were determined for both tops and bottoms of three trees in each plot. These data are summarized in Table 1. The lime-sulphur deposit interfered somewhat with the determination, but presumably, its effect was fairly constant.

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[1] Okanagan Turbo-Sprayers, Penticton, British Columbia.

TABLE 1: COMPARISON OF OIL DEPOSITS: "AIR-KING" TRAILER-BLOWER AND HAND SPRAYING

		Gal/100 gal. spray		Gal/Acre		Position	Micrograms Oil per Cm2			
Orchard	Sprayed by	Oil	Lime-Sul.	Oil	Lime-Sul.	in Tree	1	2	3	Ave.
1	Hand	2	4	20	40	Top	606	485	443	511
						Bottom	759	539	446	581
	Trailer-blower	10	20	15	30	Top	652	613	669	645
						Bottom	813	672	772	752
2	Hand	2	4			Top	395	542	743	560
						Bottom	541	646	985	724
	Trailer-blower	10	20			Top	679	482	510	557
						Bottom	648	421	428	499

Table 1 suggests that while the trailer-blower unit charged with a mixture of five times conventional concentration applied less toxicant per acre than hand application of conventional mixture, it applied as much material per tree. Doubtless this apparent anomaly is due to greater "run-off" in the case of the heavily hand-sprayed dilute mixture. It was interesting to learn from the oil deposit determinations that whereas most observers were under the impression the blower unit did not adequately spray the tree tops, actually it seems to have given more uniform spray distribution than the hand spraying. Results, in terms of oil-delayed bud development, were fairly similar in all cases.

The Okanagan experimental sprayer was used to apply a dormant oil-lime sulphur concentrate but at that time the "fishtail" modifications had not been completed and the machine had not been calibrated. Consequently, as will be seen from Table 2, the steam-air unit gave satisfactory deposits but the hydraulic-air unit applied far too much material. Even in that case, however, the ratio between top-of-tree deposit and bottom-of-tree deposit compared favourably with hand spraying. Uniformity of deposit with the steam-air unit exceeded that of hand spraying.

TABLE 2: COMPARISON OF OIL DEPOSITS: OKANAGAN EXPERIMENTAL SPRAYER AND HAND SPRAYING

	Gal/100 gal spray		Gal/Acre (Approx.)		Position	Micrograms Oil per Cm2			
Sprayed by	Oil	Lime Sulphur	Oil	Lime Sulphur	in Tree	1	2	3	Ave.
Hand	2	5	8	20	Top	198	240	164	201
					Bottom	352	304	293	316
Steam-Air	20	40	8.5	17	Top	950	1590	464	1000
					Bottom	1230	1160	973	1120
Hydraulic-Air	20	40	11	22	Top	772	420	435	542
					Bottom	668	438	598	568

In this experiment hand application was not as heavy as in the aforementioned trials with the trailer-blower unit and a rather stiff breeze was blowing while the work was in progress. It is particularly interesting, therefore, to note that the steam-air unit charged with a mixture ten times as concentrated as was applied by hand and using very little more oil per acre, gave oil deposits that were more uniform and about twice as great. Delayed bud development was negligible both after the hand-spraying and the steam-air application, but was pronounced in the hydraulic-air block as would be expected from the excessive deposits there.

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[5] Hand spraying in the various experiments was done by members of the staffs of the British Columbia Department of Agriculture (Messrs. R. Wilson, A. Watt, H. H. Evans, W. Baverstock and D. Allen) and of the Dominion Entomological Laboratory, Summerland (Messrs. C. V. G. Morgan, M. D. Proverbs, R. S. Downing and I. C. Carne).

These experiments suggest that, in applying dormant oil sprays as concentrates, less oil is necessary per acre than in the case of conventional hand-spraying; perhaps two-thirds as much would suffice to give satisfactory deposits. There seems no reason to feel that the application of dormant oil concentrates is likely to be a risky procedure provided the equipment is calibrated beforehand and operated at uniform speed. It is doubtful, nevertheless, if oil concentration should exceed the maximum, 20 per cent, that was employed in this work.

Early in the autumn, fruit samples were collected for DDT analysis from two of the experimental plots. Table 3 summarizes the determinations.

TABLE 3: COMPARISON OF DDT DEPOSITS: "AIR-KING" TRAILER-BLOWER, OKANAGAN EXPERIMENTAL SPRAYER AND HAND SPRAYING

Sprayed by	Orchard	Weeks Between Spraying and Sampling	Lb. 50% DDT/ 100 gal.	Approx. lb. 50% DDT/acre	DDT-micrograms Cm2 (Ave. of triplicates) Tree Top	Bottom
Hydraulic-Air	1	6	24	21	2.0	6.7
Steam-Air	1	6	24	21	2.6	6.7
Hand	1	6	1.6	24	1.6	2.9
Trailer-blower	2	8	7.5	15	0.1	1.4
Hand	2	8	1.5	15	0.8	1.6

These DDT deposits indicate that neither the Okanagan experimental sprayer nor the trailer-blower unit was as efficient in covering the tree tops when the trees were in full foliage as when dormant. The deposits from hand spraying were about half as great in the tops as on the lower parts of the trees, those from the experimental sprayer were about one-third as great, and those from the trailer-blower considerably less than that. On the other hand, deposits in the lower parts of the trees were heavier with the experimental sprayer than with hand spraying while those with the trailer-blower unit, which operated midway between the tree rows, were fairly similar to hand spraying. It should be borne in mind that weathering of deposits in the tree-tops probably was greater than in the lower parts of the trees. As air-blast equipment becomes more generally used, no doubt trees will be pruned to allow better air circulation.

An interesting point of difference between the application of dilute spray mixtures and concentrates is that with the former the desirability of maximum retention of deposit has been emphasized; with the latter, maximum "run-off" seems required. The reason for this difference is that when a concentrate machine operates close to the trees, branches immediately in front of the air vent are subjected to a heavier spray load than those some distance away. This is particularly the case when foliage is heavy. One of the present undertakings of the Summerland laboratory is a search for surface active compounds that will bring about minimum retention of summer spray deposits while not seriously reducing their resistance to weathering.

Pest Control in Experimental Orchards

The results of some representative trials of concentrate sprayers are now briefly reviewed.

1. *San José Scale*

The trailer-blower unit was used to apply two dormant spray mixtures for control of San José scale, *Aspidiotus perniciosus* Comst., in a heavily scale-encrusted orchard; some details have been given under Table 1. There was an increasing scale population across the orchard from plots 1 to 4 before the experiment was undertaken and this should be kept in mind in considering Table 4.

TABLE 4: COMPARISON OF "AIR-KING" TRAILER-BLOWER UNIT AND HAND SPRAYING: PER CENT SAN JOSE SCALE-INFESTED DELICIOUS APPLES

Plot	Sprayed by	Gal./100 gal. spray		Gal./Acre		% Scaled Fruit
		Oil	Lime Sul.	Oil	Lime Sul.	
2	Hand (Exper. Staff)	2	4	20	40	0
3	Trailer-blower (conventional mixture)	2	4	20	40	0.3
4	Trailer-blower (concentrate mixture)	10	20	15	30	3.8
6	Owner	–	–	–	–	50.8

Under conditions of the experiment the performance of the trailer-blower unit was considered to be reasonably satisfactory.

2. *Lygus Bugs on Peach*

The Okanagan experimental sprayer was used to apply DDT-stove oil concentrates to a number of one-half-acre or one-acre blocks of peach trees that, in previous years, had been subject to *Lygus* bug attack as manifested by that malformation of fruits commonly called "catfacing". In general, the results were encouraging; a measurable degree of improvement was obtained in several cases by the high-speed application of a concentrate of DDT 4 lb.-stove oil 1 gal. per acre at the petal-fall period.

3. *Peach Twig Borer*

Good control of peach twig borer, *Anarsia lineatella* Zell., was accomplished in two orchards by the steam unit and by the hydraulic unit of the experimental sprayer using either lime-sulphur concentrate or DDT concentrate at the pink stage of flower-bud development. The results were evidently comparable to those from hand spraying.

4. *Codling Moth*

Concentrate sprayers were used for control of codling moth, *Carpocapsa pomonella* L., on a number of large blocks of apple trees in three orchards. Using three to four cover sprays good control was obtained in all cases by DDT concentrates; these, in some applications, were admixed with the acaricide monoethanolamine dinitrocyclohexylphenolate. In Table 3 an estimate of DDT deposit has been given for two of the orchards; codling moth control for the same orchards is given in Table 5.

TABLE 5: COMPARISON OF CODLING MOTH INFESTATIONS: OKANAGAN EXPERIMENTAL SPRAYER, TRAILER-BLOWER UNIT AND HAND SPRAYING

Sprayed by	Orchard	Per Application		Average wormy Apples
		lb. 50% DDT /100 gal.	Approx lb. 50% DDT/acre	
Hydraulic-Air	1	24	21	0.5%
Steam-Air	1	24	21	0.5%
Hand	1	1.6	24	0.6%
Steam only	1	–	15	7.2%
Trailer-blower	2	7.5	15	0.2%
Hand	2	1.5	15	0.04%

5. *European Red Mite*

Since the advent of DDT the European red mite, *Paratetranychus pilosus* (C. & F.), has become the most troublesome pest of the British Columbia tree fruits industry. It is very difficult to control and in an insidious way is capable of causing great losses. A spray applicator that will handle a heavy infestation of European red mite will, in all likelihood, be capable of handling any of the other spray-controlled British Columbia orchard pests. Against this mite concentrate sprayers have been used in a considerable number of trials and, with one exception, gave results comparable to heavy hand spraying. Results from typical orchards are summarized in Table 6. The acaricide in use was monoethanolamine dinitrocyclohexylphenolate.

TABLE 6: COMPARISON OF EUROPEAN RED MITE INFESTATIONS: OKANAGAN EXPERIMENTAL SPRAYER AND HAND SPRAYING

Sprayed by	Orchard	oz. DNCHP /100 gal.	Approx. oz. DNCHP/acre	Ave. Mites per Leaf Before Spray	Ave. Mites per Leaf After Spray
Steam-Air	1	32	24	86.0	19.1
Hydraulic-Air	1	32	24	43.9	42.2
Hand	1	2	28	81.7	93.2
Steam-Air	3	32	16	133.6	9.1
Hydraulic-Air	3	32	16	136.0	33.6
Hand	3	2	16	70.4	31.9

Table 6 suggests that the steam-air system of the Okanagan experimental sprayer was distinctly more effective in controlling European red mite with dinitrocyclohexylphenol than was heavy hand spraying, and the hydraulic-air system was perhaps slightly more effective than the hand applications. It will be observed that none of the procedures appeared to have given outstanding control. Doubtless this reflects the fact that the weather was too cool to permit a high measure of toxicity from dinitrocyclohexylphenol and, in addition, the foliage was sampled where spray coverage from the experimental machine would be low, i.e., in line-of-row, near the periphery of the tree. The object of sampling from that position was to make sure that the concentrate equipment was not favoured; hand spraying should be as thorough over that portion of the tree as any other. The general appearance of experimentally sprayed trees a week after spraying indicated good commercial control.

In two other orchards an over-all summer spray schedule was carried out on large blocks of trees by concentrate equipment. DDT-monoethanolamine dinitrocyclohexylphenolate mixture with or without stove oil was used in three applications. Control of European red mite apparently was satisfactory. To sum up: although control of European red mite by concentrate equipment so far has been encouraging, those who have had much experience with that redoubtable pest would agree that it is yet too soon to be satisfied.

6. *Pear Psylla*

It has been mentioned that two commercial adaptations of the Okanagan experimental sprayer became available late in the season and were used in trials against the pear psylla, *Psylla pyricola* Foerst. That insect is capable of increasing with great rapidity when conditions are sufficiently humid to be to its liking. Consequently, if it can be controlled even reasonably well by high-speed spray equipment the problem of additional applications will not be nearly so important as with hand spraying. The experiments were conducted in two Bartlett pear orchards in which the trees were approximately 15 to 18 feet high. A comparison was made in the first orchard between the Okanagan experimental sprayer steam-air system, the same sprayer with hydraulic-air system, the modified Besler steam sprayer (with attached blower), the "Okanagan Turbo-Mist" sprayer, and thorough hand spraying. Later trials in the second orchard involved only the modified Besler steam sprayer and the "Okanagan Turbo-Mist" sprayer after certain modifications had been effected in each.

TABLE 7: COMPARISON OF PEAR PSYLLA INFESTATIONS: OKANAGAN EXPERIMENTAL SPRAYER, MODIFIED BESLER STEAM SPRAYER, "OKANAGAN TURBO-MIST" SPRAYER AND HAND SPRAYING

Sprayed by	Material	Toxicant /100 gal.	Approx. Toxicant /acre	Nymphs per 60 leaves Tree Tops	Bottoms
Exper. Hydraulic-Air	Nicotine sulphate 40%	15.7 pt.	14 pt.	17	7
	Summer oil	8 gal.	7.2 gal.		
Exper. Steam-Air	Nicotine sulphate 40%	15.7 pt.	14 pt.	14	17
	Summer oil	8 gal.	7.2 gal.		
Commercial Steam-Air	Nicotine sulphate 40%	26.5 pt.	12 pt.	45	3
	Summer oil	15 gal.	6.1 gal.		
Turbo-Sprayer	Nicotine sulphate 40%	16.6 pt.	13 pt.	15	9
	Summer oil	8.2 gal.	6.6 gal.		
Hand	Nicotine sulphate 40%	1 pt.	13.5 pt.	9	6
	Summer oil	0.5 gal.	7.2 gal.		
Check (no Spray)				206	1019

TABLE 8: COMPARISON OF PEAR PSYLLA INFESTATIONS: "OKANAGAN TURBO-MIST" SPRAYER AND MODIFIED BESLER STEAM SPRAYER

Sprayed by	Material	Toxicant/ 100 gal.	Toxicant/ Acre	Nymphs per 60 leaves Tops	Bottoms
"Turbo-Mist"	Parathion 18%	4.5 lb. (as 18%)	3 lb. (as 18%)	0	0
"Turbo-Mist"	Chlorinated Camphene 40%	13.2 lb. (as 40%)	10 lb. (as 40%)	6	23
Modified Besler Steam-Air	Chlorinated Camphene 40%	19.5 lb. (as 40%)	10 lb. (as 40%)	35	45
Check — no spray				145	347

Table 7 indicates that the Okanagan experimental sprayer charged with nicotine sulphate-summer oil concentrate was slightly less effective against pear psylla than careful hand spraying with approximately 1350 imperial gallons of conventional dilute nicotine sulphate-summer oil mixture. Neither the commercial steam-air machine nor the commercial hydraulic-air machine appeared to do quite as good work in the tree-tops as the experimental sprayer. Several changes in these machines were made and further trials, as in Table 8, indicated an improvement, particularly in the hydraulic-air unit ("Turbo-Mist Sprayer").

Discussion

The foregoing data point to the probability that concentrate sprayers will prove sufficiently effective in the hands of Canadian fruit-growers to give pest control equal to that generally attained by conventional hydraulic machines. Nevertheless, very difficult pest control problems have not been the rule in British Columbia orchards during the three years since the high-speed sprayer project was initiated. Only in further experience will there be complete assurance.

At this point it will be well to discuss the significance of beneath-the-tree operation. In conventional hand spraying good control of many pests is only attained when a tree is sprayed from beneath (or within) as well as from without. This is partly because some of our most troublesome pests, such as orchard mites, feed extensively on the undersides of the leaves and on the inner branches; and partly because adequate penetration of foliage and uniform spray deposits cannot be attained when the tree is sprayed only from without. When "automatic" or air-blast sprayers first came into use they travelled the centres of the rows and directed highly diluted spray fog to both sides simultaneously. In order to obtain the necessary carrying power and the necessary air turbulence, a great deal of power was required; some of these machines absorbed about 100 horse-power in developing the airstream. Since velocity in the centre of an airstream varies linearly with the reciprocal of the distance from the air vent, the distance over which it is desired to obtain effective action is of great importance. For example, to obtain a given velocity at 40 feet (which might be the effective distance in a widely planted orchard with between-the-row operation) about 50 horsepower would be required for emission to one side whereas with the same outlet, equal velocity at 25 feet (as in beneath-the-tree operation) would require about 12 horsepower.[§]

If spray machinery is to pass beneath the trees it should not deleteriously compact the soil; consequently, all components of equipment for beneath-the-tree operation must be relatively small and light and the equipment should have a large area of contact between wheels and ground. This means that it should operate with concentrated spray mixtures instead of the highly dilute mixtures presently in general use.

One of the most important considerations in the use of concentrate machines is maintenance of uniform slow speed, not exceeding 1·5 miles per hour. It is not easy for a tractor driver to gauge his speed and there is a tendency to accelerate. Unless the tractor is equipped with a specially geared speedometer the operator should estimate speed by rate of spray output and by occasional timing in feet-per-minute from tree spacing. Taking as an example the "Okanagan Turbo-Mist" Sprayer: providing the driver operates the sprayer motor at the recommended constant speed, is careful to watch the pump pressure and to ensure that all nozzles are in operation, he can gauge correct rate of travel by working to about 50 imperial gallons output per acre for rows 30 to 35 feet apart and about 80 gallons for rows 20 to 25 feet apart. Concentrations of spray chemicals are calculated on the same basis, i.e., for summer sprays 15 to 20 times conventional concentration, for dormant oil sprays 8 to 12 times conventional.

To judge from the experiments of the last three years, evidently care should be taken to avoid either extremely concentrated or unduly dilute mixtures. Dilute mixtures tend to defeat the purpose of the lightweight machine; excessive concentration tends to bring about inadequate or dust-like coverage, owing perhaps to excessive evaporation of the liquid component before it strikes fruit or foliage. Probably this condition is most likely to occur in arid fruit growing areas; perhaps it could be overcome by addition of a suitable petroleum fraction to summer spray concentrates. Because of the danger of excessive deposits, however, and the tendency of oils to increase likelihood of injury from certain foliage sprays, such a practice will require careful investigation.

[§] Correspondence with W. F. Campbell, Division of Mechanical Engineering, National Research Council, Ottawa.

The point of greatest significance for the fruitgrower in the operation of these high-speed sprayers is their saving in terms of labour overhead; this amounts to over 80 per cent. At the same time they make an easy job of what has heretofore been a messy and tiring one. In the face of high labour costs and a declining market, economy in operation is bound to be given particular consideration.

SUMMARY

1. A project on the development of lightweight high-speed orchard spraying equipment was initiated by the Dominion Division of Entomology at its Summerland (British Columbia) laboratory in 1946.

2. In this project attention has been directed both to the examination of factory-built orchard sprayers and dusters, and more particularly, to the development of high-speed equipment adapted for use with light tractors.

3. Pest control realized from high-speed sprayers has not been consistently as effective as that from the most careful hand work employing up to 1500 imperial gallons of dilute spray per acre. In general, however, it appears to have been as effective as now commonly attained in the Canadian tree-fruits industry. Orchard dusters have been less efficient than concentrate sprayers and are not being given further consideration.

4. Although trials on exceptionally severe outbreaks of the most serious British Columbia orchard pests have yet to be made, the following have been satisfactorily controlled by concentrate sprayers: European red mite, codling moth, peach twig borer, *Lygus* bugs, San José scale.

5. Because middle-of-the-row operation of air-blast spray equipment involves high capacity blowers and hence heavy and expensive equipment, the use of such equipment is not feasible for growers with light tractors such as most Canadian growers possess.

6. It seems probable that the conventional hydraulic sprayer with its spray guns will soon be replaced by light and moderately priced "automatic" machines using spray mixtures some 8 to 20 times as concentrated as those now in general use. These so-called concentrate machines handled entirely by the tractor driver, effect a saving of over 80 per cent in labour and are neither unpleasant nor difficult to handle; they operate close to the tree rows and spray approximately 2 acres per hour.

7. Of two such light machines already in production, one is based in part on an experimental sprayer built by the Dominion Department of National Defence for the British Columbia and Dominion Departments of Agriculture. The other, which is now being manufactured in British Columbia, is based entirely on the experimental sprayer.

8. Concentrate sprayers have performed satisfactorily in the application of dormant oil sprays for which purpose 20 per cent oil appears to be a maximum. Since oil deposition from a concentrate has been

more efficient than from conventional dilute spray mixture, evidently the per-acre oil dosage of a concentrate need only be about two-thirds as great as is now customary.

9. Dormant spray deposits from concentrate sprayers have, in general, been somewhat more uniform throughout the tree than from hand spraying; summer spray deposits, on the contrary, have been less uniform.

ACKNOWLEDGMENTS

The project on development of spray applicators was established largely through the efforts of Mr. W. A. Ross, Chief, Fruit Insects Investigation Unit, Division of Entomology, Science Service, Ottawa. Mr. Ross has given this work his strongest support.

Through the kindness of Dr. H. M. Barrett, Superintendent of the Defence Research Experimental Station, Suffield, Alberta, the excellent facilities of the Suffield workshops were made available for construction of the Okanagan experimental sprayer. Mr. F. E. Owen of the Suffield Station directed construction of the sprayer and suggested several of its original features.

Suggestions were also made by Messrs. Ben Hoy and R. P. Murray, horticulturists of the British Columbia Department of Agriculture. Without the financial aid provided by that Department construction of the experimental sprayer might have been considerably delayed. Accordingly, special thanks are due the Provincial Horticulturist, Mr. W. H. Robertson and the Minister of Agriculture, Honourable Frank Putnam.

Mr. G. F. Lewis, Dominion Entomological Laboratory, Summerland, B.C., serviced all concentrate spray equipment as well as contributing to the final design of the Okanagan experimental sprayer.

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SOME WARTIME PROBLEMS OF INSECT INFESTATION IN AUSTRALIAN STORED WHEAT

By Frank Wilson, Division of Economic Entomology, C.S.I.R., Canberra

During the first world war, unprecedented wheat stocks accumulated in Australia and those responsible for the grain's safety were caught unaware by mouse and weevil plagues that, in terms of the losses caused, were perhaps the most catastrophic in history. A graphic description of the plague, the efforts made to cope with it, and the damage caused, have been provided by Winterbottom (1922).

After the beginning of the second world war, the newly formed Australian Wheat Board, though forewarned of the dangers of long-term wheat storage, was by no means prepared technically to prevent these outbreaks developing or to deal with them when they arose.

As compared with the first world war, the problem, in some ways, was more complex. On the earlier occasion, virtually the whole of the wheat was held in bag-stacks, and as the conditions of storage were basically the same everywhere, a solution appropriate to the form of storage would have been generally applicable. During the recent war, on the other hand, in different parts of the country, wheat was stored in bags, in silos and terminal elevators, and in bulk storages of various types—known variously as bulkheads, bins, bulk depots, and emergency bulk storages. The common characteristic of this last group was that the wheat was held in bulk in a single mass in a large shed, the size of individual sheds ranging up to huge structures one-third of a mile in length and with a capacity of ten million bushels.

The problems, therefore, were more varied than in the earlier war. On the credit side, the centralization of control under the Australian Wheat Board made possible a uniformity of directives for the safe keeping of the wheat, and a greater freedom to move out particular parcels of wheat that threatened infection of surrounding stocks. Another advantage was that the creation of the C.S.I.R. Division of Economic Entomology between the two world wars had provided Commonwealth research workers able to analyse the problems and prepare solutions for the difficulties that lay ahead. The war had not been long in progress, in fact, before the Division of Economic Entomology accepted the responsibility of advising the Australian Wheat Board on its problems of insect infestation and a small team of workers, led initially by Mr. F. N. Ratcliffe, was formed.

Initially, a good deal of attention was paid to bagged wheat. Policy here aimed at preventing insect outbreaks, for it then seemed unlikely that an economic method of treating infested bagged wheat would be developed. The use of permanent sheds, which were usually old structures with raised floors, impossible to disinfest, was discouraged. Stacks were generally constructed on "open sites" which were already surrounded by mouseproof fencing before the stack was erected. These fences were very effective when care was taken that they remained mouseproof. This was seen clearly when, for lack of materials, a stack was left unproofed beside other stacks built in the usual way within mouseproof fences. Such unproofed stacks commonly became much more heavily infested.

Although mice were numerous in the stacks at times, nothing approaching the severity of a plague was experienced, and it is by no means certain that, had a plague developed, the mouseproofing would have proved adequate to circumvent serious results.

When the wheat was received from the farmer at the siding it was stacked and roofed immediately within mouseproofing. Then as soon as the railways were able, it was transferred to bag-depots.

These bag-depots were constructed at key points determined as far as possible by climatic considerations—we aimed at selecting the driest and coolest areas—but within the practical limits set by the transport requirements essential to the industry. At these depots, which were comparatively few in number, it was possible to take great trouble to maintain the area free from pests, to check that wheat was free from infestation before it was admitted to the depot, and to draft out quickly any parcels of wheat subsequently showing weevil infestation.

On the other hand, the bag-stacks at the numerous and widespread receival sidings could not be so carefully tended, and wheat was not meant to remain there for more than some months.

Within limits, the system worked very well indeed, and wheat at the bag-depots remained in good condition though stored for as long as three or four years. The weak point proved to be the carrying capacity of the rolling stock, for, as the war progressed, wheat stocks piled up at the sidings and serious infestation, chiefly by rice weevil, developed.

It seemed that these infestations might eventually get beyond control, and that a method of treating the wheat must be found which, besides being reasonably cheap, required no more labour or materials than the extremely difficult and limited labour and supply position permitted. This meant, among other things, that the bag-stacks could not be dismantled but must be treated *in situ*. As these were very long, roofed structures, it would also be impracticable to enclose them totally for fumigation purposes.

In the warm Australian climate the main factor making for insect infestation in stacks of bagged wheat is the build-up in moisture content of the layer of bags at the base and at the walls of the stack. Infestation normally begins in the lowest tier and gradually spreads up the walls, the interior of the stack and its upper part, where the moisture content stays low, remaining comparatively free from weevils.

Upon investigation, it was found that heavy fumigants, like carbon bisulphide or methyl bromide, when applied to the upper surface reached the bottom of a stack rapidly by gravitational displacement: also, that if the fumigant were prevented from escaping through the sides of the stack, the rate of fumigant loss by diffusion through the top of the stack was very slow.

These facts, taken together, allowed us, by airtight enclosure of the stack walls and application of the fumigant to the upper surface, to obtain, with normal fumigant dosages and very low costs, highly satisfactory insect kills in stacks of any size (Wilson and Gay, 1946).

This simple method of stack fumigation was applied extensively to millions of bushels of wheat and proved quite satisfactory. Combined with good preventive measures in bag-depots, it now permits the long-term storage of bagged wheat without fear of heavy loss.

One of the most interesting problems investigated was that of insect infestation in the vast mounds of wheat held in the "bulk depots". The absorption of radiant heat by the iron roofs of these structures raises wheat temperature considerably and tends to limit moisture-content increase after the wheat is stored. In consequence, it is *Rhizopertha dominica*, an insect with comparatively high temperature but low moisture-content requirements, that is the principal pest under these conditions of storage.

The damage caused by this insect and others in bulk depots is almost entirely restricted to the periphery of the wheat mass. The great bulk of the wheat does not suffer appreciable damage, and, in fact, when infested, rapidly reaches combinations of temperature and moisture content that are lethal to the insects. The restriction of serious infestation to a shallow zone at the periphery of the mound results from the liberation of heat by the insects and the low rate of heat conductivity in wheat. In consequence, infested wheat heats rapidly to a point near the limit for insect reproduction at the given moisture-content, so that the rate of reproduction soon becomes very low. At the periphery of the wheat mound (particularly at the exposed surface) heat is lost to the atmosphere, and this creates at the surface a temperature gradient in which the insects can generally find temperatures very suitable for their reproduction. At the same time, wheat at the surface may increase in moisture content by taking up moisture from the atmosphere and by the movement of moisture to it from the inner wheat mass. This inner wheat, already barely able to support the insects becomes completely unsuitable to them by virtue of this gradual moisture loss, but its temperature is maintained or increased by the activity of the insects in the moister peripheral wheat layer (Wilson, 1946(a)).

These infestations, which took the form of expanding "hotspots" in the bulk depots, seemed likely to prove very difficult to control.

However, we had done a good deal of work on mineral dusts, and a number of Australian materials had been produced which, while not as effective as one would have wished, nevertheless compared quite well with those available commercially from other countries (Gay, 1947). Now the creation of new infestations in a depot (as distinct from expansions in existing infestations) resulted from insects flying about the depot and settling down again in uninfested areas. As this involved passing through the surface of the wheat mound, it created the possibility of preventing new infestations by applying a layer of mineral dust upon the wheat surface. This was done both experimentally and commercially on a large scale, and was found to reduce considerably the incidence of new infestations.

These dusts were not capable, however, of dealing with established infestations. As infestations tended to begin near the wheat surface and as the process of heating tended to compel a very great majority of the insects to return to the surface layer of wheat, infestation was principally a surface phenomenon, and we found that the direct application of certain liquid fumigants would give a high percentage kill of insects in these "hotspots".

This combination of mineral dust treatment over the whole of the wheat surface and fumigation of infestations developing despite the dust barrier, was applied extensively and proved very effective at extremely low cost. Although shortages of materials and labour made it impossible to apply the method with a normal degree of efficiency, the infestations in the bulk depots so treated never threatened to get beyond control, and of wheat stored continuously for up to three years in different depots virtually the whole was passed on to the market in first-class condition.

Since that time more effective dusts have been evolved. One of my colleagues (Gay, 1947), for example, has shown that the addition of DDT or gammexane increases enormously the efficiency of the dusts we actually used in this work. It seems to me, therefore, quite certain that future uses will be found for such improved mineral dusts in the treatment of stored bulk wheat.

These then were a few of the main wheat storage problems that concerned us during the war. My main impressions, after participating in what proved to be a very satisfactory campaign against wheat pests, are the following:

Firstly, that grain handlers should not attempt long-term and large-scale grain storage without the technical support of good scientific advisers.

Secondly, that these advisers should work as much in the field as in the laboratory, so that theoretical possibilities can be examined in the light of practical necessity.

Thirdly, that it is the scientific advisers' duty also to expand the basic understanding of wheat storage problems on which future improvements in storage methods must be based.

Fourthly, that good transport facilities, enabling ready wheat movement, can rectify many failings in a storage system. This is especially so if the country concerned has a large internal consumption of wheat.

Fifthly, that the primary requisite for safe storage is a storage structure that is proof against rain and soil water and sufficiently aerated to prevent excessive temperature increase by absorption of radiant energy.

Sixthly, that the main emphasis in the control of pests in stored wheat should be placed upon the prevention of infestation, but that appropriate curative measures must nevertheless be devised to cope with breakdowns in the preventive system.

Finally, I should like to express the conviction that probably the next advance in dealing with this problem lies in evolving economic methods of controlling the temperature and relative humidity surrounding the mass of wheat. In Australia, at least, this atmosphere commonly renders the wheat more suitable for insect infestation. If we could modify this atmosphere so that it made the wheat not more susceptible but less susceptible to insect attack, then we should have advanced very far along the road to really sound methods of wheat storage.

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PROTECTION OF CANADIAN GRAIN IN STORAGE AND TRANSIT[1]

By H. E. GRAY, Stored Product Insect Investigations, Division of Entomology, and W. N. KEENAN, Plant Protection Division

WHILE there has been a great industrial development in Canada within the past ten years, the production and export of grain is still one of the most important factors in the Canadian economy. All cereals are subject to insect infestation and this paper deals briefly with some of the more important problems which have arisen, particularly between 1939 and 1945, and the way in which they have been solved.

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[1] Contribution No. 2581, Division of Entomology, Science Service, Dominion Department of Agriculture, Ottawa, Canada.

Normally, Canada is singularly free from insect pests of stored grain. It is only in times of congestion and "dead storage" that these problems arise. The usual markets for Canadian grain were cut off by the advance of the Axis powers over Europe, and Canada was faced with an enormous storage problem.

Food was a very important consideration to the Allies. One of Canada's greatest contributions during the war was the production of cereal grains and flour, and the safe storage and transport of these commodities overseas.

Grain growing in Canada is largely concentrated in the Prairie Provinces where large amounts of spring wheat, oats, and barley and smaller amounts of rye and flax are produced. This area has a continental climate characterized by hot summers, cold winters, and light rainfall. Much of the grain produced in this area is exported, while the bulk of the grain grown elsewhere in Canada is used domestically.

The major problem in grain storage in Canada is to keep it dry. If harvested under dry conditions, grain can be successfully stored for two years or more. The growing season is short and harvesting is often carried out before the grain is fully mature. Even in uniformly dry grain, translocation of moisture within the bin can occur during storage because of the great temperature differential set up within large bulks of grain in severe winters. Moisture greatly accelerates insect infestation.

Storage Facilities

At the outbreak of war, Canada had commercial storage for about 450 million bushels of grain. Over 5,600 country elevators scattered throughout the Prairies had a capacity of about 190 millions, and 110 larger elevators of the terminal type provided most of the remainder.

Country elevators are the usual means by which grain enters commercial channels. Their function is to receive grain from the growers, to weigh and bin it according to grade and to ship it by railroad cars to terminal points when carloads of a particular grade are accumulated.

En route to the terminal, each carload of grain is examined by an inspector of the Board of Grain Commissioners and an official grade is given to the individual carlot.

The Canadian system of handling and exporting grain is considered by importers, bankers and the trade generally to be the finest in the world, the most rapid and at the same time the most economical.

Emergency Storage in War Years

To augment the existing storage facilities, a large number of wooden annexes were built at country points in 1939 and 1940. Most of these were about 60 feet long, 30 feet wide, and 20 feet high to the plate, with a peak roof; each had a capacity of about 30,000 bushels. They were located close to the country elevators so that the grain could be spouted to the roof of the annexe. Use was also made of empty buildings of all kinds to provide additional storage.

Large "distress storage" units similar in general plan to country annexes were also built to supplement the terminal elevators. These had a capacity of from 200 thousand to 5 million bushels each. Most of these buildings had concrete floors and wooden superstructures with central belt facilities for loading and unloading. The grain varied in depth from about 18 feet at the walls to about 45 feet under the belt.

The farms in Western Canada have storage for approximately 860 million bushels of grain, consisting of outside granaries and bins in barns. The shortage of farm storage at times made it necessary to leave the grain outside in piles. These were placed on high ground, surrounded by drainage ditches and covered with waterproof paper.

OFFICIAL ENTOMOLOGICAL ORGANIZATION

The overall insect control programme in Canada has been possible through the co-operation of three government agencies: The Board of Grain Commissioners, Department of Trade and Commerce, which regulates the handling and marketing of grain, having jurisdiction over grading, weighing, storing, etc.; the Stored Product Insect Unit of the Division of Entomology, Department of Agriculture, which is in charge of investigational work in connection with the insect pests of stored grain and other stored commodities; and the Division of Plant Protection, Dominion Department of Agriculture, an inspection service, which carries out much of the actual inspection of boats, elevators, warehouses, etc., for purposes of insect control.

METHODS OF OPERATION

As there are no "weevilly" grades in connection with Canadian export grain, when insect pests are found in elevators the control treatment is carried out under the authority of the Board of Grain Commissioners. In practice, most of the entomological supervision is carried out by officers of the Division of Entomology.

As the personnel of the Division of Entomology assigned to this work was small, it was necessary to secure the complete co-operation of the grain companies in providing information with respect to infestation and assistance in the control phases of the programme. Both country and terminal elevator agents forwarded samples whenever pests were encountered. These resulted in the prompt detection of insect infestation and greatly facilitated the reduction of losses. Approximately five thousand samples were examined per year and specific information regarding the control of the pests was furnished to the company concerned.

In addition, special surveys were conducted in relation to more serious pests such as the rusty grain beetle, the Indian meal moth, rice and granary weevils and spider beetles. Assistance was rendered to the grain trade in securing insecticides and arrangements were made for the prompt movement of grain when necessary.

Grain cars that had carried infested grain were found to retain large numbers of insects. When it was necessary to ship infested grain, the bill of lading bore such an endorsement. This grain was placed in terminal bins where it could be fumigated if necessary and the railroad cars which had carried it were thoroughly cleaned following unloading. Grain infested with rice and granary weevils was fumigated and moved into consumption in such a way that contamination of elevators and transportation facilities was avoided. In all, a well integrated system of detection and control was inaugurated.

EDUCATION

Although advice to management assisted in the reduction of infestation, it became very apparent that further improvement in control could be brought about only by having men trained in grain sanitation resident at each elevator to deal with insect troubles promptly.

A series of short courses was held at Montreal, Toronto, Fort William, and Vancouver, which were largely attended by personnel selected from each elevator staff. Lectures, educational films, and practical demonstrations were used to train those in attendance. At its conclusion, the men returned to their respective elevators and have since continued to carry out the recommended controls in a very satisfactory manner.

INSECT CONTROL ON LAKE BOATS

The winter storage of grain afloat is a well established practice on the Great Lakes. The boats are loaded at Fort William just prior to the close of navigation and proceed to destination at one of the Georgian Bay or Lower Lake elevators. The cargoes are unloaded during the winter or early spring. This practice eased the storage problem at the Lakehead during the war years.

Upon arrival at Fort William, a boat intending to take on grain for winter storage was examined and, if it were in a satisfactory condition, a loading certificate was issued. If cleaning was necessary, this was carried out by the ship's crew and the boat was then re-inspected. This procedure enabled the boat to load with a minimum amount of delay. Of the 816 grain cargoes involving 191 million bushels of grain stored on boats during war years, there was not a single complaint of insect infestation.

INSECT CONTROL ON OCEAN-GOING VESSELS

The need for clean transport for the overseas shipment of food was apparent at the outbreak of war. Essentially insect-free grain could be delivered to the ships at seaboard. All boats carrying grain and cereal materials overseas were examined and were treated, if necessary, before loading.

Following the sinking of many of the newer boats, it was necessary to employ older, less desirable ones, many of which harboured insect infestations. The inspectors, usually two in number, went aboard the boat and after securing information regarding previous cargoes, made a complete examination of the hold space. If the boat was clean, a loading certificate was issued. Cereal debris and light infestations were often found. In such cases, cleaning was carried out followed by re-inspection. In badly infested boats, control measures were carried out by commercial pest control firms. After the treatment of the boat, it was re-inspected.

Two types of treatment were used: (1) contact sprays, and (2) fumigation. During war years, it was necessary to maintain convoy schedules. The use of contact sprays although not so effective as fumigation, enabled loading to proceed within an hour after this type of treatment as no aeration was required. There was also the advantage that the crew could remain on board during treatment. Contact sprays of extract of pyrethrum in a high grade water-white oil carrier gave satisfactory results.

Fumigation with HCN at a dosage of 8 ounces or more per 1,000 cubic feet of space was used in a number of boats. Individual holds were fumigated successfully. Since the war, some work has been done with methyl bromide which has proved to be even more satisfactory than HCN.

The aeration of boats after fumigation was important. When there was little air movement and the relative humidity was high, the fumigant was not readily dissipated. Under such circumstances, forced ventilation was essential and greatly facilitates the aeration. Gas concentration tests should always be made by the fumigator before allowing other personnel to enter the holds.

Since the war, considerable attention has been devoted to the inspection of stowage sacks. These are carried by the boat from port to port and used to prevent shifting of the cargo in transit. As the boats carry cargoes from many countries, the sacks sometimes become infested. The inspection detects such infestation and these sacks are now (post war) fumigated to prevent the transfer of insects to clean Canadian grain. Insect free bags are now available to the ships loading in Canada.

During war years a total of 2,791 boats carried approximately 480 million bushels of grain and 2,250 thousands of tons of flour. Only one adverse report came from the British Ministry of Food. The results were so satisfactory that the same programme is being continued in connection with all overseas shipments of grain and cereal products.

INFESTATION IN GENERAL

Most of the insect or mite infestation occurred in grain stored in temporary facilities. The "dead" storage in such structures had several disadvantages. The large grain mass changed very little in temperature during the winter except at the surface, where moisture accumulated because of the temperature differential. Roof leaks and floor cracks also permitted moisture to reach the grain and promoted economic infestations of insect pests.

The detection of insect infestation was a primary problem. Grain temperatures and probe samples were taken at frequent intervals throughout the mass of grain as a check on its condition. Special probes were developed for deep sampling. Patches of "tough" grain on the surface in the winter indicated "hot spots" deep in the grain. The fact that most of these occurred in the central part of the grain mass reduced the area in which intensive probing was necessary.

There was a series of entomological problems. In 1940 and 1941, grain mites were the principal pests. In 1941 there were a few infestations of the rusty grain beetle, *Laemophloeus ferrugineus* (Steph.), and by 1942 this insect was the major pest. Both the rice weevil *Sitophilus oryza* (L.), and the granary weevil, *Sitophilus granarius* (L.), were recovered for the first time in commercial grain in southern Manitoba. Numerous surface infestations of spider beetles *Ptinus* spp., were also found in stored wheat. Psocids, *Liposcellis divinatoria* (Müll.), proved to be capable of causing grain to heat in the large annexes.

Under the control programme, the direct damage to the grain was small. The most abundant pests encountered were species which attack the germ end of the kernel or feed in the grain debris. There was appreciable indirect damage due to increase of temperature and increase of the moisture content of the binned grain. In some cases the damage was sufficient to result in the lowering of the grade of the grain, and it was also necessary to "turn" and move large quantities of grain.

The actual damage from all sources was relatively small, largely on account of the vigilance of the grain trade. As inspection crews were maintained continuously in the storages to check the condition of the grain, they were able to detect infestation in the initial stages.

Success in safeguarding Canadian grain during war years was the result of several factors: (1) Canada has a short season in which pests can be active, and grain can be cooled and safely stored for a long time. (2) Preventive measures formed the backbone of the control programme. The grain trade maintained a constant check on stocks and reported infestations promptly. After being emptied, the storages were cleaned, repaired, and sprayed to prevent infestation. Railroad cars which had carried infested grain were thoroughly cleaned before re-use. (3) Insect infestations were dealt with promptly by fumigation, by the use of contact sprays or by the movement and cleaning of the grain.

BREEDING SPRING WHEATS FOR RESISTANCE TO WHEAT STEM SAWFLY ATTACK[1]

By A. W. Platt, Dominion Experimental Station, and C. W. Farstad, Dominion Entomological Laboratory, Lethbridge, Canada

Introduction

The wheat stem sawfly (*Cephus cinctus* Nort.) is a major pest of wheat in the open plains region of North America. In addition to the Canadian provinces of Alberta, Saskatchewan and Manitoba, it has been reported from twelve of the western and mid-western states of the United States of America. This insect is a native of the mixed grass prairie where it infested various grasses, chiefly of the genus *Agropyron*.

Fletcher (3) first reported sawfly attacking wheat in Canada at Souris, Manitoba, in 1895. Since that date its economic importance has increased steadily. During the first two decades of the present century rapid settling of the prairie areas was folowed by a tremendous increase in wheat acreage and a subsequent invasion of this crop by the sawfly. Local and widespread fluctuations in the intensity of the outbreaks have been recorded from time to time. The most important factors contributing to the periodic reductions in population have been determined. The first wheat varieties introduced on the Canadian plains were subjected to very severe epidemics of stem rust, and a very high proportion of the sawfly larvae contained within the wheat stems were destroyed along with the host plant. In order to escape the rust epidemics large acreages of durum wheats, which had some sawfly resistance, were grown. The use of crop rotations, including such immune crops as oats, barley and flax, reduced the infestations materially. Occasionally, under favourable weather conditions one of the native parasites, *Microbracon cephi* Gahan, was able to reduce severe infestations to non-economic levels.

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[1] Joint contribution from Cereal Division, Experimental Farms Service, and the Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada. Contribution No. 149 of the Cereal Division. Contribution No. 2584 of the Division of Entomology.

The use of earlier maturing, rust-resistant wheat varieties, all highly susceptible to sawfly attack, grown in wheat-fallow rotations provided conditions for rather steady increases in infestation and subsequent damage. In addition, certain soil conservation practices, such as surface tillage, strip farming, and the general use of the combine harvester, aggravated the problem.

On Canadian prairies, annual losses of at least 20 million bushels of wheat occurred between the years 1938 and 1948 (Farstad—unpublished).

Criddle (1) and Seamans (9) have outlined the life history of the sawfly. The adult, emerging in early summer, deposits eggs inside the developing wheat stem. The larva feeds on the inside of the stem, migrating to the base as the stem matures and girdling it at ground level, thus causing it to break over easily and fall to the ground. Such stems are difficult to retrieve with modern harvesting equipment and constitute the most obvious loss from the activities of this insect. In addition, a loss of 10 per cent results from a reduction in bushel weight and grade even if all of the fallen stems are recovered (10).

A co-operative project between the Dominion Experimental Station, Swift Current, Saskatchewan, and the Dominion Entomological Laboratory, Lethbridge, Alberta, was initiated in 1932 with the objective of studying sources of resistance to sawfly attack and the development of agronomically desirable varieties of hard red spring wheat having resistance to sawfly damage. This paper summarizes some of the more pertinent results that have been obtained.

METHODS OF DETERMINING RESISTANCE

The methods used in determining the reaction of wheat varieties and hybrid lines to sawfly damage have been reported (6). Briefly, the varieties were grown in single-row plots, the rows being 10 feet long and spaced 1 foot apart. These nurseries were seeded on summer-fallowed land adjacent to infested stubble, with the rows sown at right angles to the source of infestation. Usually four replicates were sown, as this number yielded results sufficiently precise for most purposes. The nurseries were sown early, as early-seeded wheat is most attractive to the sawflies. By following the above procedure it was usually possible to obtain a complete infestation of all varieties. When the crop was fully mature, that is, ready for combine harvesting, the damage to each plot was noted. This was done by taking the average of two independent estimates of the percentage of stems severed by the sawflies in each plot.

SOURCES OF RESISTANCE

Three main sources of resistance that have possibilities for use in a breeding programme have been found. The first of these is a group of solid-stemmed varieties of *Triticum vulgare*. These were obtained from Dr. O. Frankel, Lincoln College, Christchurch, New Zealand, and were originally collected in Portugal and adjacent areas. The line designated S-615 has been the most promising of this group. Platt and Farstad (6) reported that this line was much more resistant than the commonly grown Canadian varieties such as Apex and Thatcher. On the average of 24 tests, the mean percentage of stems cut was 14 for S-615, 61 for Thatcher, and 68 for Apex. While S-615 exhibited sufficiently high resistance in most years and at most stations for practical sawfly control, it occasionally showed considerable susceptibility, particularly at one station, namely, Regina, Saskatchewan. The fact that the resistance of this line can be modified by environmental conditions lessens its usefulness in a breeding programme.

The second source of resistance was the solid-stemmed variety of *T. durum*, Golden Ball. It was reported (6) that this variety was, on the average, more resistant than S-615. When conditions were favourable for the expression of the S-615 type of resistance the differences were unimportant, but Golden Ball continued to exhibit reasonably high resistance under all test conditions and hence had a better average showing. The Golden Ball type of resistance should be most useful if it can be transferred to bread wheats.

The third source of resistance was *Agropyron elongatum*, a tall wheat grass of Mediterranean origin. A small plot of this grass was included in the tests for sawfly resistance at Lethbridge, Alberta, in 1938 and 1939. Each year approximately 1,000 stems were examined. In spite of initial infestations of 100 per cent, only 1 stem was cut during these years. All of the plants were produced by clonal separation of one or two original plants.

Later, several hundred individual plants were set out at Regina, Saskatchewan, where they were exposed to sawfly infestation. In 1948 these were examined for sawfly reaction. Most of the plants exhibited a high degree of resistance but a few were cut as much as 40 per cent. If the genes for susceptibility are recessives, they may be widely distributed in the population, since *A. elongatum* is almost entirely cross-pollinated. On the other hand, as this grass is a polyploid, the presence of susceptible genes may be of little practical significance in a breeding programme.

NATURE OF RESISTANCE

Experimental work on the nature of resistance has not reached the point where any very definite conclusions can be drawn. In wheat resistance it is associated with stem solidness. No hollow-stemmed wheat has been found that has a high degree of resistance nor a solid-stemmed one that is highly susceptible. Equally solid-stemmed wheats may vary appreciably, however, in the degree of resistance exhibited. It appears that solidness of stem is a prerequisite of resistance and that some additional factor or factors are necessary for its maximum expression. Even in the grass, *A. elongatum*, most of the culms are at least partially solid but here other factors seem to be of equal or greater importance in the expression of resistance.

BREEDING PROGRAMME

The S-615 Type of Resistance

As this type of resistance can be most easily utilized in producing agronomically desirable bread wheats for this area, the greatest amount of effort has been expended on this aspect of the breeding programme. When the programme was commenced in 1938 the immediate objective was the production of a hard red spring wheat with resistance to sawfly attack, mature plant resistance to stem rust (*Puccinia graminis tritici*), reasonably good yielding capacity, and satisfactory milling and baking quality.

Studies on the inheritance of solid stem and stem rust reaction showed that three main factor pairs were involved in inheritance of the former and two in the latter character (5). These results showed that large populations would have to be grown if the desired segregates were to be obtained in reasonable numbers. With this in mind the following method of handling hybrid populations was used. The F_2 was grown in a bulk plot and exposed to an epidemic of stem rust. As it was not possible to provide an environment suitable for both a sawfly infestation and a rust epidemic in the same nursery, the solid-stem character was used as an index of sawfly resistance. A mass selection of rust resistant solid-stemmed plants was made which was grown in a bulk plot in the F_3. This plot was similarly mass-selected and the F_4 grown under a sawfly infestation where resistant individual plants were selected. These were grown as F_5 lines again under sawfly infestation. Desirable homozygous lines were tested for sawfly reaction at four stations the following year and retested for stem rust reaction. Grain from resistant lines was subjected to preliminary quality tests. Promising lines then went into regular varietal trials and standard milling and baking tests. By using bulk plots and mass selection it was possible to handle large populations with a minimum amount of skilled labour.

The practical result of this first programme was the development of the variety, Rescue. It resulted from the cross S-615 x Apex. Rescue has been shown (7) to be equally as resistant to sawfly attack as the resistant parent, S-615. It is resistant to the common races of stem rust but not to race 15B, it is susceptible to leaf rust and bunt, and it is moderately susceptible to common root rot. The yield of grain in the area of severe sawfly damage compares favourably with the varieties now being grown, such as Apex and Thatcher. Where moisture conditions are more favourable Rescue has yielded poorly. In bread-making quality Rescue is equal or superior to Marquis in protein content and loaf volume, is slightly lower in absorption, and has off-type physical properties of the dough. Approximately 75,000 bushels were distributed in 1946 and it is estimated that well over a million acres were seeded in 1948. With minor exceptions fields of Rescue have been relatively free from sawfly damage, even in the most severely infested areas.

At the present time the objective of the breeding programme is to improve the quality, disease resistance and yield of Rescue. Crosses have been made between Rescue and high-yielding, high-quality varieties such as Thatcher, Redman, and Cadet. The same general method of bulk plots and mass selection of segregating generations is being used. The programme is being speeded up by the use of a winter increase station, described by Jenkins *et al.* (4). In this programme some difficulty has been experienced in maintaining the sawfly resistance of Rescue in the hybrids produced and even greater difficulty in producing hybrids with satisfactory physical properties of the dough. It is thought that this latter difficulty can be overcome by using very large populations so that several hundred lines may be available for preliminary quality tests.

Golden Ball Resistance

An attempt to transfer stem solidness from Golden Ball to hollow-stemmed varieties of *T. vulgare* has been described (8). No solid-stemmed, vulgare segregates were obtained from the populations examined. It was postulated that a gene for hollowness exists in the C genom that is epistatic to all other genes for solidness.

Nevertheless, solid-stemmed vulgare wheats such as S-615 and the hybrid Rescue do exist. These wheats should be free from the epistatic gene for hollowness. Accordingly, Rescue was crossed with Golden Ball and the progeny is now under study. While the results are encouraging, they are not yet sufficiently extensive to warrant the conclusion that any factors for stem solidness or sawfly resistance have been transferred from Golden Ball to 21 chromosome segregates.

Agropyron elongatum Resistance

A considerable number of more or less wheat-like lines from crosses between *A. elongatum* and various wheat varieties were obtained from several investigators. This material had not been selected for sawfly resistance. When it was tested for sawfly reaction, it varied from susceptible to a degree of resistance comparable to that of S-615. In general, the more wheat-like segregates showed the greater sawfly susceptibility.

While these results were not too encouraging, they did suggest that it might be possible to transfer at least some of the factors for sawfly resistance from *A. elongatum* to wheat. Five plants of this grass were crossed with Rescue and the F_1 back-crossed to Rescue. The material has not yet been exposed to sawfly attack.

SUMMARY

During the course of these investigations three sources of resistance to wheat stem sawfly have been discovered. One of these has been utilized in the production of the new variety, Rescue, which, in commercial production, has proved to suffer negligible sawfly damage in most districts. The utility of the other sources of resistance is still under investigation.

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Discussion

In reply to Wilson (Australia) who asked if biological control had been abandoned, Van Steenburgh (Canada) stated that on the contrary it was being intensified against *Cephus cinctus.*

BIOLOGICAL CONTROL OF INSECTS

THE BIOLOGICAL CONTROL OF INSECTS IN HAWAII

By C. E. Pemberton, Hawaiian Sugar Planters' Association, Hawaii

Though great strides have been made during recent years in the development of new insecticides, biological methods of insect control continue to receive serious attention in Hawaii and are, as in the past, still proving to be the most economical and profitable means by which most destructive insects can be kept under reasonable control. The new insecticides have found their greatest usefulness against insects of the household, the greenhouse, in stored food products, in small garden plots and on ornamental plants. In such places the cost of application is not usually an inhibiting factor. The use of DDT in its various formulations has also been adopted, with good results, in the treatment of plant material held in quarantine. The only field crop treated with insecticides on a large scale is the pineapple. Systematic spraying for the control of the mealybug *Pseudococcus brevipes* (Ckll.) and its associated ant *Pheidole megacephala* (Fabr.) has been found profitable. Soil fumigation for nematode control is also extensively carried on by the pineapple growers.

Sugar cane continues to be the largest agricultural crop grown in the Islands. The present crop occupies 204,111 acres of land. Though 11 different insect pests have been established in Hawaiian cane fields for many years, it has only been necessary to use insecticides against one and this, the armyworm *Laphygma exempta* Wlk., has become greatly checked in recent years through the introduction of parasites, as discussed below. All of the others are now so well controlled by imported parasites and predators that no measurable damage by any can be computed. Prior to the application of biological control measures some of these actually threatened the very existence of the industry. Today, high production costs leave such a narrow margin of profit that the complete control of these pests by natural enemies, which cost nothing once they are established, is a vital matter in the present economy of the industry.

At previous meetings of this Association Dr. O. H. Swezey has discussed several of the serious insect pests of sugar cane in Hawaii and their natural enemies. Since his paper was presented at the Fifth Pacific Science Congress, definite improvement in the control of the armyworm *Laphygma exempta* Wlk. has been effected through the establishment of five parasites, additional to some nine others previously established in the Territory. This improved control began in 1942. All of the new parasites are endemic or indigenous to southwestern United States. These are the braconid wasps *Apanteles marginiventris* (Cresson), *Meteorus laphygmae* Viereck and *Chelonus texanus* (Cresson); the ichneumonid wasp *Pristomerus appalachianus* Viereck and the tachinid fly *Eucelatoria armigera* (Coq.).

Repeated attempts to introduce and establish natural enemies of the pineapple mealybug *Pseudococcus brevipes* (Ckll.) have met with some success but the established enemies have been effective only in very localized areas and to date they do not generally control the mealybug sufficiently to prevent the rapid spread of the so-called pineapple wilt disease, which results from feeding by this insect. Four established natural enemies are the encyrtids: *Euryrhopalus pretiosa* (Timberlake), *Anagyrus ananatis* Gahan and *Hambletonia pseudococcina* Compere and the predatory cecidomyid *Lobodiplosis pseudococci* Felt. All were imported from tropical or semi-tropical America. Fortunately successful methods of insecticidal control have been perfected though at large cost. There is still hope that more effective parasites or predators may be found.

The introduction from Puerto Rico of the tropical American toad *Bufo marinus* (Linn.) has helped considerably to check many insects, slugs and the common centipede *Scolopendra subspinipes* Leach. This toad is now common on all of the main Hawaiian Islands and has also been taken from Hawaii to many other Pacific islands, where it has been reported to be generally useful.

Because of the food value and ease with which it can be propagated in Hawaii, the sweet potato was extensively grown in the Islands during the recent war. As plantings became extensive a small leaf miner *Bedellia orchilella* Walsm. became epidemic and seriously reduced the yields. During the summer of 1945 a braconid parasite *Apanteles bedelliae* Viereck was introduced from the state of Kansas. It became quickly established and has greatly reduced the leaf miner. Another injurious vegetable insect in Hawaii is the bean capsid *Pycnoderes quadrimaculatus* Guerin. During 1943 a mymarid egg parasite of this pest was introduced from Mexico. This parasite *Anagrus yawi* Fullaway became established and is a useful addition to the Hawaiian insect fauna. Efforts to control the Harlequin cabbage bug *Murgantia histrionica* (Hahn) in 1940 with natural enemies resulted in the establishment of the encyrtid egg parasite *Ooencyrtus johnsoni* (Howard), which was obtained in California. Still another vegetable pest, the potato tuber moth *Phthorimaea operculella* (Zell.), has been checked somewhat through the introduction from California and establishment of the braconid parasite *Apanteles scutellaris* Muesebeck.

A prolific scale insect *Pinnaspis buxi* (Bouché) has been a serious pest of the coconut palm and other palms in Hawaii for many years. During 1936 a ladybird beetle *Telsimia nitida* Chapin, which is an effective enemy of *Aspidiotus destructor* Sign. in Guam, was introduced into Hawaii in attempts to control the *Pinnaspis*. It became established and in a few years had so greatly reduced the scale that damage is now negligible.

A small grasshopper *Oxya chinensis* (Thunb.) has long been a troublesome insect in Hawaiian cane fields. A scelionid egg parasite *Scelio pembertoni* Timberlake of this acridid was found near Kuala

Lumpur, Malayan Union, and introduced into Hawaii. This became established and has materially checked the grasshopper on all of the sugar plantations where it has been unduly abundant.

During 1940 the ampulicid wasp *Ampulex compressa* (Fabricius) was introduced for the control of the larger cockroaches that occur in Hawaii. It has become well established on all of the main islands. Because of its size, brilliant blue-green colour and spectacular habits, it has attracted much attention. In Hawaii it parasitizes *Periplaneta americana* (Linn.), *Periplaneta australasiae* (Fabr.) and *Neostylopyga rhombifolia* (Stoll). It has become sufficiently abundant to be of definite value.

The most serious insect pest to invade Hawaii in recent years is the Indo-Malayan fruit fly *Dacus dorsalis* Hendel. Efforts to control it with parasites are under way. At the present writing one larval parasite *Opius longicaudatus* (Ashmead) has been successfully introduced from the Malay Peninsula and is being reared in the laboratory and liberated. A detailed discussion of this fly in Hawaii is being presented to the Congress by D. T. Fullaway.

During June, 1948, the coconut moth *Agonoxena argaula* Meyr. appeared in quantity on coconut trees in Honolulu. It possibly came from Samoa where it is well known. An undetermined chalcid wasp *Brachymeria* sp., which parasitizes the pupae of this insect has been introduced from Samoa. It is too soon to know the results of this introduction. It is not uncommon for immigrant insects to become well controlled in Hawaii by parasites or predators already in the Territory. In the case of this coconut moth, investigations show that two local parasites *Zaleptopygus flavo-orbitalis* (Cameron) and *Brachymeria polynesialis* (Cameron) have already effected a considerable control of the pest.

Many insects new to Hawaii became established in the Islands during the war or shortly thereafter. The great increase in ships and airplanes coming to the Islands during this period is accountable for this. Some of the insects were beneficial and have taken their place in the complex of biological control factors now operating. Worthy of mention are an undetermined species of *Eurytoma* which heavily parasitizes the eggs of the Black Widow Spider *Latrodectus mactans* (Fabr.) and the related spider *Latrodectus geometricus* Koch; the specid wasp *Polemistus luzonensis* Rohwer which preys on Aphididae; the rhipiphorid beetle *Rhipidius pectinicornis* Thunb. which is a parasite of the common roach *Blattella germanica* (L.); the larrid wasp *Liris aurata* (Fabr.) which preys on certain crickets and the eumenid wasps *Eumenes latreillei petiolaris* Schulz, *Eumenes campaniformis* (Fabr.) and *Eumenes pyriformis philippinensis* Bequaert, all three of which capture and store certain caterpillars in their nests. The first of these has been especially valuable in checking the geometrid moth *Anacamptodes fragilaria* (Grossbeck) which badly defoliated many plants in Hawaii for some time after it invaded the Territory about 1943 or 1944. Of interest also was the first appearance in Honolulu during 1941 of the encyrtid *Comperia falsicornis* (Gomes) which was found to be heavily parasitizing the oothecae of the common household cockroach *Supella supellectilium* (Serville).

A large number of other insect pests in Hawaii are under good control through the activities of imported parasites and predators. The important ones which have not been mentioned are discussed by Dr. Swezey in a paper presented at the Fifth Pacific Science Congress.

From past experience both the Government and the large agricultural institutions of Hawaii continue to have faith in the biological method of insect control. Apparently owing to the great isolation of the Islands, the very limited insect fauna and the semi-tropical environment, this method offers greater opportunities for success than on continents, regions of the earth lying in temperate zones undergoing a definite winter season, or on large islands of continental structure and origin supporting a biota rich in species.

Discussion

In answer to Wilson (Australia) it was stated that no potato moth parasites had been introduced from South America and that *Bufo marinus* had usefully reduced centipede and slug populations. Answering Dumbleton (New Zealand) it was stated that the practice in Hawaii was to introduce complexes of primary parasites and to continue introductions till control was secured.

SOME PROBLEMS OF BIOLOGICAL CONTROL OF INSECT PESTS IN THE PHILIPPINES

By Silverio M. Cendana, College of Agriculture, University of the Philippines

The recurrence at almost regular intervals of many insect pests in the Philippines occasions tremendous losses to crops. Among the pests may be mentioned *Locusta migratoria* (Linn.) subsp. *manilensis* (Meyen), *Leocopholis irrorata* Chevr. and *Ferrisia virgata* (Ckll.) of several crops; *Leptocorisa acuta* Thunb., *Schöenobius incertellus* Walk., *Spodoptera mauritia* Boisd. and *Cnaphalocrosis medinalis* Guen. of rice; *Pyrausta nubilalis* Hübn. and *Calandra oryzae* Linn. of corn; *Olethreutes schistaceana* Sn., *Trionymus sacchari* Ckll., *Topeutes auriflua* Zell., and *Ceratovacuna lanigera* Zehnt. of sugar cane; *Heliothis armigera* Hubn. and *Gnorimoschema heliopa* Low. of tobacco; *Oryctes rhinoceros* Linn. and *Rhynchophorus ferrugineus* Fabr. of coconut; *Cylas formicarius* Linn. of sweet potato; and *Agromyza phaseoli* Coq. and *Aphis* spp. of beans.

The frequent heavy infestations by these pests show that they are not sufficiently kept down by their natural enemies, so that there is room for augmenting their natural enemies by introducing foreign species.

Attempts were made to introduce into the Philippines beneficial species for the control of phytophagous forms. The crested myna, *Acridotheres cristatellus* (Linn.), was introduced from India during the later years of the Spanish regime to help in the control of the migratory locust. This bird is now a permanent component of the fauna of Luzon Island, where it helps to a certain extent in keeping down rice armyworm infestation. In 1928, nine birds of the British Indian mynah, *Acridotheres tristis* (Linn.) were imported from Hawaii by the Philippine Sugar Association and were released in the fields of the College of Agriculture at Los Baños, Luzon Island. Since their release, however, no specimen of the bird has been collected, so it is presumed that it failed to become established. At about the same time, the Philippine Bureau of Plant Industry introduced the toad *Bufo marinus* from Hawaii and this species is now well established and may be found in many localities in Luzon; it is also widely distributed on the island of Negros.

Among the entomophagous insects introduced into the Philippines were *Cryptolaemus montrouzieri* Muls. from Hawaii for mealybugs (1928), *Trichogramma minutum* Riley from Hawaii for eggs of Lepidoptera (about 1930), *Euplectrus platyhypenae* Ashm. from Hawaii for the rice armyworm (1928), *Opius* spp. from Hawaii for the melon fly (about 1925), *Encarsia flavoscutellum* Zehnt. for the woolly sugar cane aphis (from Java in 1928 and Formosa in 1929), *Ceromasia sphenophori* Vill. from Hawaii (1928) for *Trochorrhopalus strangulatus* Gyll., and two scoliid wasps from Australia for white grubs (1932). The results of these introductions have not been encouraging. Owing perhaps to unsatisfactory experience from these introductions, this method of pest control in the Philippines does not receive the attention that the more agriculturally advanced countries are giving to it.

The success in establishing *Cryptolaemus montrouzieri* in Bukidnon, Mindanao Island, but failure in Luzon, Negros and Panay furnishes a good lead in the analysis of the difficulties of biological control work in the Philippines.

The writer had in a small measure helped in the effort to establish *Cryptolaemus* in Luzon. From 1928 to 1931, over 3,000 adults reared in the laboratory from a few adult *Cryptolaemus* introduced from Hawaii by the Philippine Sugar Association were liberated in the fields of the College of Agriculture at Los Baños and at various altitudes up to 1000 metres on Mount Maquiling. Except for a single adult that Uichanco and Villanueva[½] found on February 10, 1932, in the College Experiment Station, where most of the releases were made, the beetle apparently failed to become a part of the insect fauna of the Los Baños area.

Living beetles released in Calamba and Canlubang, province of Laguna, Luzon Island, in La Carlota, Negros Island and in Central Pilar, Panay Island, likewise failed to become established in these places. The Del Monte Pineapple Company, however, succeeded in establishing the ladybird, and a neuropteron, in its pineapple plantations in Bukidnon, Mindanao Island.

Uichanco and Villanueva attribute, in part, the failure of *Cryptolaemus* to become established in Los Baños to ants which molested the beetles. The fact that some of the beetles gained a foothold, at least for a time, shows, however, that there must be a more important cause for the failure. In making a more determined effort to establish the beetle, the ants might be poisoned with ant bait prior to the liberation of the insect.

The highly accentuated seasonal fluctuations in available supply of food as Uichanco and Villanueva pointed out has possibly worked against *Cryptolaemus montrouzieri* in the Los Baños area. *Ferrisia virgata* (Ckll.), the most abundant mealy bug which could have

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[½] UICHANCO, L. B. and VILLANUEVA, F. E., 1932. Biology of the pink mealy bug of sugar cane, *Trionymus sacchari* (Ckll.) in the Philippines, *Phil. Agri.* 21: 205-276.

served as a reliable food supply for the beetle, occurs in great abundance on many plants on the college campus for about three months (February, March and April), but after this season specimens can hardly be obtained.

The failure of *Cryptolaemus* to thrive in the College of Agriculture, on Mount Maquiling, in Calamba and Canlubang in the province of Laguna (Luzon Island), in La Carlota (Negros Island) and Pilar (Panay Island), on the one hand, and its successful colonization in the province of Bukidnon, Mindanao Island, on the other seem to point to climatic conditions as the limiting factor in introduction of beneficial insects in the Philippines.

The chief factors of Philippine climate that affect insect life are rainfall and typhoons. There are four types of climatic areas in the Philippines, the extent of each of which and their characteristics are shown in Fig. 1.[2]

The province of Laguna, Luzon Island, La Carlota (Negros Occidental), and Pilar (Capiz Province, Panay Island) all have the *Type I* climate, which is characterized by a prolonged dry season from December to the early part of May, and a very pronounced wet season from June to November. Bukidnon, Mindanao Island, has the *Type IV* climate which has no pronounced wet season but a short dry season.

Heavy rains, especially if accompanied by strong wind, are very effective in reducing the number of insects that are exposed, unless these are provided with effective protective covering, such as overlapping scales or an impervious coat of wax. The parasitic forms are especially adversely affected because they are small, naked and with shorter life cycle. The observation of Uichanco[3] that the tachinid parasites of *Olethreutes schistaceana* are most abundant during February and March, which are dry months, in Los Baños, and the common observation that the eggs of the citrus bug, *Rhynchocoris longirostris* Stal, are more highly parasitized during the dry than during the wet months support this statement.

The prevalence of typhoons in a locality may make it more or less unsuitable for certain forms because the insects, being small and fragile, especially if winged, would be killed by strong winds accompanied by heavy rains.

In 1928, the writer observed closely the effects of a typhoon on the insects in a sugar cane field in Los Baños. The wind blew down all the cane plants, many of the stalks were broken, and the leaves either torn off the plants or shredded into strips. In parts of the field where insects were abundant a few days before the typhoon, there were none visible the following day. It was only four days after the typhoon that a few leafhoppers could be found here and there, and two or three freshly emerged nymphalid butterflies appeared. Even one month after the typhoon had passed, insects were still very much fewer than before the storm.

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[2] The writer is indebted to Director Casimiro del Rosario of the Philippine Weather Bureau for furnishing him with this chart and other charts showing the tracts of destructive Philippine typhoons, as well as information on the rainfall in the different parts of the country.

[3] Uichanco, L. B., 1926. Factors influencing periodicity in the abundance of certain forms of terrestrial insect life in the Philippines, *Phil. Agri.* 15: 403-408.

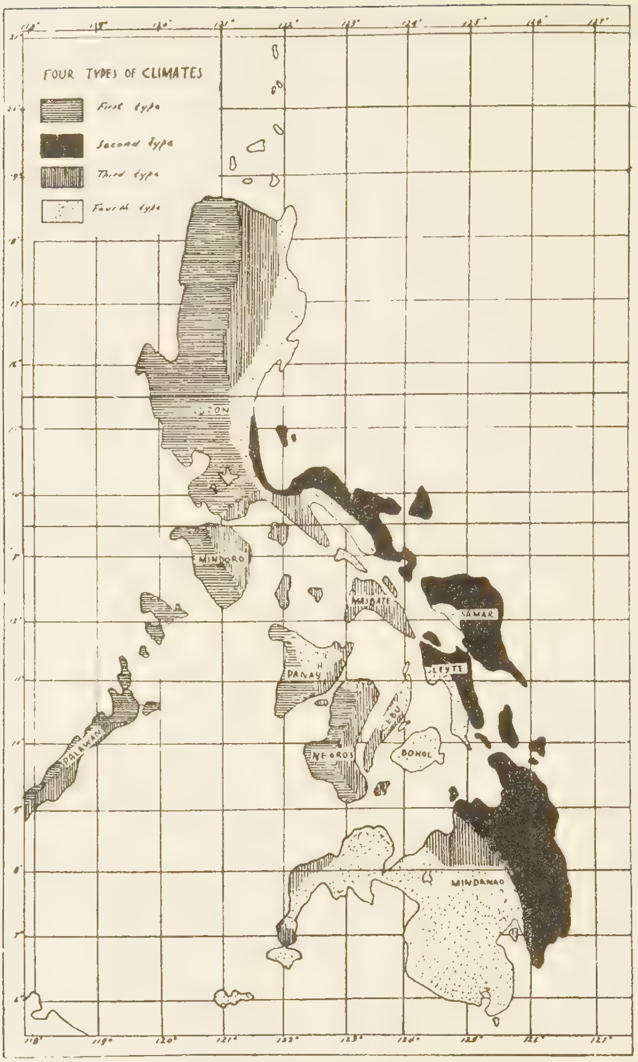
FOUR TYPES OF CLIMATES
First type
Second type
Third type
Fourth type
LUZON
MINDORO
MASBATE
SAMAR
LEYTE
PANAY
NEGROS
CEBU
BOHOL
PALAWAN
MINDANAO

FIG. 1.–THE FOUR TYPES OF PHILIPPINE RAINFALL CLIMATE
(From the Philippine Weather Bureau)

First Type: Two pronounced seasons, one dry in winter and spring, the other wet in summer and autumn. All the regions on the western part of the islands of Luzon, Mindoro, Negros and Palawan are of this type.

Second Type: No dry season; with a very pronounced maximum rain period in winter. In this class fall the Catanduanes, Sorsogon, the eastern part of Albay, the eastern and northern part of Ambos Camarines, a great portion of the eastern part of Quezon, Samar, the eastern part of Leyte, and a large section of eastern Mindanao.

Third Type: No very pronounced rain period; with a short dry season lasting only from one to three months. Regions with this type of climate are western part of Cagayan, Isabela, Nueva Vizcaya, the eastern portion of the Mountain Province, southern Tayabas, the Bondoc Peninsula, Masbate, Romblon, north-east Panay, eastern Negros, central and southern Cebu, part of northern Mindanao, and most of eastern Palawan.

Fourth Type: No dry season and no very pronounced maximum rain period. The regions affected by this type are the Batanes Province, north-eastern Luzon, western Ambos Camarines, Albay, eastern Mindoro, Marinduque, western Leyte, northern Cebu, northern Negros, and most of central, eastern and southern Mindanao.

Although the areas covered by the four climatic types in the Philippines are exposed to typhoons, five latitudinal belts have been differentiated by the Philippine Weather Bureau. Each belt differs from the others with respect to the frequency of typhoons passing through the area.

Cryptolaemus failed to become established in areas more or less frequently visited by typhoons. The province of Laguna is in a belt visited by typhoons fairly frequently; and Negros and Panay are in a belt of frequent destructive typhoons. Bukidnon Province, in which the beetle was successfully colonized, is in the belt that is almost free from typhoons.

Since climatic conditions exert a deciding part in the successful colonization of introduced species, and because of the diversity of climatic conditions that exist, the Philippines, for purposes of biological control work, may be divided as follows:

1. Areas with *Type I* climate and those with *Types III* and *IV* which are in the paths of frequent typhoons. These are poor places in which to colonize introduced beneficial insects. In order to succeed in the use of foreign entomophagous insects to control pests, it may be necessary to "reseed" every year, until the introduced forms have adapted themselves to the climatic peculiarities in the area. Extreme fluctuations in density of the native parasites exist. The island of Luzon (except Tayabas and the Bicol Peninsula), Mindoro, Masbate, Romblon, and the western side of the islands of Palawan, Panay and Negros are in this area.

Areas with *Type II* climate in which colonization will most likely not succeed no matter how vigorous the effort. The eastern parts of the islands of Mindanao and Leyte, the islands of Catanduanes, Alabat and Samar, and the eastern side of the Bicol Peninsula extending northward to eastern Tayabas are included in this area.

3. Areas with climate *Types III* and *IV* (except those in the paths of frequent typhoons), where conditions for insect life are most favourable, and where colonization of introduced species of insects will be likely to succeed. Mindanao (except the eastern slope), south-eastern Palawan, the eastern and northern sides of Negros, the western slope of Leyte, Cebu, the western side of the Bicol Peninsula, and southern Tayabas are included in this area.

The diversity of climate and the fact that the Philippines is comprised of numerous islands must be, to a large extent, responsible for the existence of distinct sub-areas. These sub-areas differ from each other to a greater or less degree with respect to biota.[4] Uichanco[5] pointed out " . . . we should not overlook the fact that to each island in the Philippines, many other islands of the Archipelago are, biologically speaking, 'foreign countries', wherein species of natural enemies of restricted geographical distribution may occur".

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[4] R. C. McGregor in 1920 was able to recognize eleven Philippine biological sub-provinces on the basis of bird distribution.

[5] Uichanco, L. B., 1928. How Luzon and Negros may help each other in the control of sugar cane pests, *Cane* (published by the Provincial Carnival Association for the Provincial Carnival held at Bacolod, Occidental Negros, P.I., April 7 to 17, 1928): 46-52.

There is no intensive survey of parasites in the different islands of the Philippines, and unfortunately, the collection of Philippine entomophagous materials with known host species that had been accumulated during 20 years of rearing, together with the unpublished manuscript based on these materials were destroyed during the war. There are known instances, however, of the same insect pest being attacked by different series of parasites in two different localities. Pierce[6] found the parasites *Phanurus beneficiens* (Zehnt.), *Macrocentrus* sp. and *Cryptus* sp. on *Topeutes auriflua* Zeller in Negros. Uichanco[7] found only the parasite *Elasmus zehntneri* Ferriere in addition to *Phanurus benficiens* on the same pest in Luzon. The tachinid parasite that is found abundantly on the larva of *Olethreutes schistaceana* in Luzon is not found in Negros. A more comprehensive survey of Philippine entomophagous insects may reveal similar instance of natural enemies found in one island but not in the others in the Philippine Archipelago.

SUMMARY

Of a number of introduced entomophagous insects only one seems to have become definitely established in the Philippines. The failure to become established seems to be due to a certain extent to (a) lack of sufficient vigour of the introduction, (b) ants that interfere with the activity of the introduced species, (c) lack of adequate food for the introduced forms at certain critical periods, and (d) climatic conditions.

Climatically, three different areas of the Philippines which differ with regards to the feasibility of establishing entomophagous insects may be recognized: (1) Areas in which colonization of introduced species could not possibly succeed because of excessive rainfall the year round; (2) areas in which permanent colonization may not succeed because of periodic heavy rains and strong winds, but in which biological control may be effected by periodic "reseeding" of the beneficial forms; and (3) areas where introduced entomophagous insects may very probably succeed in becoming established because of even, non-excessive distribution of rainfall throughout the year, and which are almost free from destructive typhoons.

DISCUSSION

Arising from this Miller (New Zealand) discussed the importance of factors of the physical environment in relation to the establishment of insects.

Pemberton (Hawaii) instanced the effect of birds on *Polydesma* outbreaks in Hawaii.

O'Connor (Fiji) attributed the failure of *Cryptognatha* to establish in a certain island to the activity of the ant *Pheidole megacephala*.

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[6] PIERCE, W. D., 1929. Notes on the sugar cane insect situation in Negros, *Sugar News*, 9: 616-625.

[7] UICHANCO, L. B., 1928. A conspectus of injurious and beneficial insects of sugar cane in the Philippines with reference to Luzon and Negros, Rept. Comm. Cane Varieties, Diseases and Fertilizers, Sixth Ann. Convention, Philippine Sugar Association, Manila, P.I. Sept. 17-23, 1928.

THE RHINOCEROS BEETLE (*ORYCTES RHINOCEROS* L.) SITUATION IN THE PALAU ISLANDS AND THE INTRODUCTION OF TWO SCOLIID PARASITES TO COMBAT THIS PEST

By T. R. GARDNER, Bureau of Entomology and Plant Quarantine,
U.S. Department of Agriculture

INTRODUCTION

THE Palau Islands, which are part of the Western Carolines, are located about 400 miles directly east of Mindanao in the Philippines. Previous to World War II they were included in the Japanese Mandated Islands, but now, as a result of the war, they are included in the Trust Territory of the Pacific Islands and are administered by the United States Navy.

One of the main agricultural crops important in the native economy of the Islands is the coconut palm. It furnishes an important item in the native food, the dried husk is used for fuel and for making fibre, and the leaves are used for thatching the native houses and weaving baskets. Copra, one of the few products of commercial value in the Islands, provides a cash income.

The rhinoceros beetle, *Oryctes rhinoceros* L., a destructive pest of the coconut palm throughout South-east Asia, East Africa, Formosa, the Philippines, the Dutch East Indies and Samoa was first observed by the natives in the Palau Islands in 1942. The Japanese entomologist T. Esaki, in several articles published in 1939 and 1940 on the insect fauna of the Japanese Mandated Islands, does not list this beetle. So it can be assumed that its introduction into the Palaus has been comparatively recent, probably brought in on Japanese ships which were operating extensively between the Palau Islands, the Dutch East Indies and the Philippines previous to and during the early part of the war.

Because of the rapid spread of this beetle, its increasing destruction to the coconut palm and the resultant effects on the welfare of the natives, the United States Naval Administration in May, 1947, requested the Pacific Science Board of the National Research Council to make recommendations for controlling this pest. As a result of these recommendations the writer was loaned to the Pacific Science Board by the Bureau of Entomology and Plant Quarantine, of the United States Department of Agriculture, for a period of six months to study the situation and introduce parasites to combat the beetle. In addition, Mr. Harold Compere, who was in South Africa on an entomological mission for the University of California Citrus Experiment Station, was loaned to the Pacific Science Board for several months in the fall of 1947 to collect parasites of the rhinoceros beetle in East Africa and ship them to the Palau Islands. After Compere returned to South Africa at the end of 1947 the work was continued by Dr. F. X. Williams, formerly with the Department of Entomology of the Hawaiian Sugar Planters' Association, who also was in Africa for the Pacific Science Board collecting parasites to combat the giant African snail, *Acatina fulica*, which is destructive on Guam and other Micronesian islands.

SURVEY OF THE PALAU ISLANDS

The writer arrived in the Palau Islands October 13, 1947, and made an extensive survey on the more important Islands of Babelthaup, Koror, Arakabesan, Malakal, Peleliu and Angaur to determine beetle abundance, distribution, injury to the coconut palm and to spot locations for future parasite liberations.

The beetle was found on all the Islands surveyed. In some areas the crowns of the coconut trees were so severely damaged by beetle attacks that no coconuts were being produced and the trees were either dead or dying. Larvae in all stages, indicating continuous breeding throughout the year, were extremely abundant in dead standing trees and fallen logs. It was not uncommon to find 30 or more full grown larvae in a three foot section of a log, in addition to many smaller larvae. On the Islands of Koror, Arakabesan and Malakal all trees were either dead or dying, with a heavy infestation of larvae in the dead logs. The trees on the southern end of Babelthaup were heavily infested with a large proportion of them dead or dying. The northern part of the Island was not as heavily infested indicating a northern movement of the beetle. Trees on the Islands of Peleliu and Angaur also were heavily infested, with many of them dead or dying. In several locations on the Islands the coconut trees had been killed by aerial and naval bombardment during the war and these dead trees have provided abundant breeding material for several years, and no doubt have been partly responsible for the rapid increase and spread of the beetle throughout the Islands.

Since dead coconut trees, logs and stumps provide the favourite material for the beetle to breed in and these occurred abundantly throughout the Islands, it was recommended to the authorities that an immediate programme be initiated to systematically destroy all such material.

Introduction of a Scoliid Parasite from Malaya

The writer arrived in Malaya mid-December, 1947, in search of *Oryctes rhinoceros* parasites for introduction into the Palau Islands. Headquarters were established at Kuala Lumpur, capital of the Federation of Malaya, where Mr. F. Burnett, Director of Agriculture, and Mr. H. T. Pagden, Senior Entomologist, very kindly provided laboratory facilities and assisted the writer in his mission. After considerable search a promising parasite was eventually located in beetle infested coconut palm groves along the west coast of Malaya in the State of Selangor. This was a fairly large scoliid with distinct yellow and black markings determined as *Scolia patricialis* Burm. Efforts were concentrated on collecting and shipping females to the Palaus. Although this parasite was quite abundant, females were difficult to collect because of their rapid movements. Two shipments of this parasite were sent from Kuala Lumpur by aeroplane. The first consignment consisting of 49 females was shipped February 5, 1948, and arrived in the Palaus February 9. One female died en route and the remaining 48 were liberated on the day of arrival on the Island of Koror.

The second consignment consisting of 64 females was shipped March 3, 1948, and arrived in the Palaus March 8. The writer accompanied this shipment on his return trip to the Islands. One female died en route and the remaining 63 were liberated on the Island of Koror the day of arrival.

Introduction of a Scoliid Parasite from East Africa

In the fall of 1947 H. Compere went to East Africa to collect *Scolia ruficornis* F., a known parasite of *Oryctes rhinoceros*, for shipment to the Palau Islands. When Compere returned to South Africa at the end of the year the work was continued by F. X. Williams. Collections of this medium sized, black scoliid were made on the Island of Zanzibar and at Mombasa in Kenya Colony where the adults were fairly abundant. Because of poor aeroplane connections and shipping difficulties in the Far East, all shipments were sent by aeroplane via the United States, Honolulu and Guam. A total of six shipments of this parasite were sent from East Africa, the first four by Compere and the last two by Williams.

The first consignment consisting of 66 females and 3 males was shipped November 16, 1947, and arrived in the Palaus December 4. Forty-five females were alive on arrival and these were liberated on the Island of Babelthaup on the day of arrival.

The second consignment consisting of about 100 females and a few males was shipped November 23, 1947, and arrived Honolulu December 4. All were dead on arrival at Honolulu.

The third consignment consisting of 78 adults, mostly females, was shipped December 7, 1947, and arrived Honolulu January 9, 1948. All were dead on arrival at Honolulu.

The fourth consignment consisting of 81 adults, mostly females, was shipped December 14, 1947, and arrived Honolulu January 12, 1948, with 26 females alive. These were fed honey and water and shipped to the Palaus the same day, arriving there January 20. Fifteen females were alive on arrival and these were liberated on the Island of Babelthaup on the day of arrival.

The fifth consignment consisting of 32 reared cocoons was shipped February 8, 1948, and arrived Honolulu February 18. These were held at Honolulu but no adults emerged.

The sixth consignment consisting of 181 adults was shipped June 14, 1948, and arrived in the Palaus June 30. F. X. Williams accompanied this shipment on his return to the Islands. Fifty-seven females were alive on arrival and 50 of these were liberated on the Island of Babelthaup on the day of arrival. The remaining seven females were used in breeding work and later one of these females was liberated.

Conclusion

It is not yet known whether the two introduced parasites have become established in the Palau Islands. Ecological conditions in the Islands are favourable for their establishment. Owing to the habits of the parasites it is doubtful if they will attack *Oryctes* larvae in coconut logs. However, the surveys showed sufficient host larvae in organic matter in the soil for them to parasitize. If they become established on the Islands of liberation they can easily spread to the other nearby Islands, as both species are strong fliers.

The Civil Administration Unit of the Palau District in its January-March 1948 Quarterly Report states that the natives have started to destroy all dead coconut trees, logs and stumps as was recommended. This programme is very important at present as it will decrease the enormous amount of breeding material present on the Islands and thus materially reduce the beetle population. By the elimination of this favourite source of breeding material the beetle will be forced to breed in organic matter in the soil and thus give the parasites, should they be established, a greater opportunity to combat the beetle.

DISCUSSION

O'Connor (Fiji) commented on the great increase in dynastid beetles in war damaged coconut areas in New Britain.

BIOLOGICAL CONTROL OF INSECT PESTS IN BRITISH COLUMBIA[1]

By A. B. BAIRD, Biological Control Investigations Unit, Division of Entomology, Ottawa, and J. H. McLEOD, Biological Control Investigations Laboratory, Vancouver, Canada

IN utilizing the biological method in the control of injurious insects, efforts have been directed for the most part against pests accidentally imported from other countries without their natural enemies which help in keeping them in check in the country of origin. Such introduced pests are usually quite immune to attack by native species and the introduction and distribution of foreign parasites and predators has produced very gratifying results. Investigations which have been carried on with increasing intensity for more than half a century have shown wide variation in the particular kinds of natural enemies and the degree of control exerted by each throughout the range of distribution of a pest so that even in the case of an indigenous insect the distribution of parasites and predators as between one part of its range and another separated by natural barriers may prove very beneficial. Canada has many such natural barriers and particularly the Prairies and the Rocky Mountains form barriers of sufficient magnitude to greatly retard or even prevent the spread of insects from coast to coast. The first work on biological control of pests in British Columbia was concerned with the transfer of parasites and predators from the Eastern Provinces.

Early developments in this field were reviewed at the Pacific Science Congress held at Vancouver, British Columbia, in 1933 and will be referred to but briefly here. In 1916 the predaceous mite, *Hemisarcoptes malus* Schiner, was introduced from New Brunswick and during the thirty years since its establishment has been an important factor in keeping the oyster shell scale at a low level of infestation. The reduction of scale infestations on wild trees and shrubs has been an important factor in this connection. *Aphelinus mali* (Hald.), a parasite of the woolly apple aphid was introduced from Ontario to the lower Fraser Valley in 1921 and to the Okanagan Valley in 1929. It is now generally distributed throughout the fruit growing areas of the province and has reduced the aphid from a most serious pest to one of minor importance. Although the application of DDT for codling moth control has proven temporarily detrimental to *Aphelinus*, it appears that an adjustment can be made in the spray schedules which will allow the parasite to continue its good work.

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[1] Contribution No. 2580, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.

Direct introduction of foreign parasites began in 1928 with the importation from England and release of *Blastothrix sericea* (Dalm.), a parasite of the European plum lecanium scale, *Eulecanium coryli* (L.), in the Vancouver area. This scale had for many years been a troublesome and serious pest of deciduous trees and shrubs in Vancouver and adjoining municipalities. Parasite distribution was continued until 1931 by which time parasitism had reached 95 per cent in the area of original release. In 1932 a parasitism of from 80 to 100 per cent occurred throughout the infested area and in 1933 the host population was so reduced that it was practically impossible to find any unparasitized scales. The scale has since been found in several new areas but due to the natural spread of the parasite, no serious effects have been noted.

The European earwig, *Forficula auricularia* L., was first reported in British Columbia in 1916 and within the next ten years had become a serious pest in Vancouver and adjacent areas. During the years 1928 to 1931, a total of 1,100 adults of a tachinid parasite, *Bigonichaeta setipennis* (Fall.), obtained from England, were released at Vancouver and New Westminster. As no evidence of establishment had been obtained by 1933 arrangements were made to procure stock of the parasite from the City of Portland, Oregon, in 1934 and as a result of propagation work carried out at the Dominion Entomological Laboratory, Victoria, British Columbia, more than 260,000 parasites were released during the period 1934 to 1939. Recovery collections made in 1938-39 showed establishment of the parasite at all release points and recent reports by King, Spencer and other entomologists working in the area indicate that very valuable control has resulted. The earwig has since become a serious pest in the interior and southeastern part of the province and distribution of the parasite in these areas is now being arranged.

The satin moth, *Stilpnotia salicis* (L.), an insect introduced from Europe, was discovered in New Westminster in 1920. The infestation soon developed to serious outbreak proportions in the willow and cottonwood stands of the lower Fraser Valley and was spreading rapidly in all directions. Three species of parasites, *Compsilura concinnata* (Meig.), *Meteorus versicolor* (Wesm.) and *Apanteles solitarius* (Ratz.), were introduced from New Brunswick and Massachussetts between 1929 and 1934. One of these in particular, *A. solitarius*, increased and spread with great rapidity and due to the fact that it produces several generations annually while the satin moth has but one generation a year, the infestation decreased in severity very rapidly and no widespread outbreak has occurred since 1934.

Introduction of parasites of the codling moth, *Carpocapsa pomonella* (L.), was attempted on a small scale at various times by several entomologists interested in its control but it was not until the summer of 1933 that an organized programme of introduction was undertaken. During that summer, and for several years following, the parasite *Ascogaster carpocapsae* (Vier.) was propagated at the Dominion Parasite Laboratory, Belleville, Ontario, and released throughout the Okanagan Valley. Its establishment was later demonstrated by recovery at several points. More recently (1946-47) two species of parasites, *Cryptus sexannulatus* Grav. and *Ephialtes caudatus* (Ratz.), attacking the spun-up larvae have been released at selected points in the Okanagan Valley but due to the scarcity of hosts during 1947 their establishment is very doubtful. This project is being further developed with particular reference to an investigation of the relation between chemical and biological control of all orchard pests.

The larch sawfly, *Pristiphora erichsonii* (Htg.), was discovered in British Columbia in 1933 and beginning in 1934 the introduction of parasites was carried out. The larval parasites, *Mesoleius aulicus* (Grav.) and *Bessa selecta* (Meig.), were obtained by transfer from the Province of Quebec where they had been established for more than twenty years. Another parasite, *Zenillia nox* Hall was obtained from Japan. The cocoon parasite, *Tritneptis klugii* (Ratz.), was already present having apparently been introduced accidentally with its host. Parasite distribution was continued until 1941 by which time all species were well established throughout the area of infestation except *Z. nox* which has not yet been recovered. Although *B. selecta* and *T. klugii* have been important, along with many other control agencies, forest entomologists who have followed the situation carefully consider *M. aulicus* as the major factor in control and give it credit for saving the valuable larch forests from destruction. As the sawfly has spread to new areas it has been closely followed by *Mesoleius* and no destructive outbreaks have developed.

In the lower part of Vancouver Island the English holly is a much prized decorative shrub and several large plantations furnish considerable revenue from the sale of cuttings for the Christmas trade. A severe infestation of the holly leaf-miner, *Phytomyza ilicis* Curt., made them completely valueless for either purpose. During the period 1936-39 five species of parasites, *Chrysocharis gemma* (Walk.), *Chrysocharis syma* (Wlk.), *Cyrtogaster vulgaris* Wlk., *Opius ilicis* Nixon and *Sphegigaster flavicorius* Wlk., were introduced from England. Following their establishment a gradual decrease in infestation by the leaf-miner was noted as the parasites increased in numbers and effectiveness. A survey during the fall of 1948 showed excellent control by the parasites in most cases except where clean cultivation is practised around the shrubs. This is probably connected with the survival and overwintering of the parasites, particularly *Chrysocharis gemma*, the most abundant species, but the situation is being investigated with a view to making the control more effective.

The peamoth, *Laspeyresia nigricana* (Steph.), was introduced into Canada from Europe prior to 1893 but was first reported from British Columbia in 1934 at which time it was abundant at Sumas Prairie. Three species of parasites, *Ascogaster quadridentatus* Wesm., *Glypta haesitator* Grav. and *Angitia* sp. were imported from England and liberated in the Sumas area during the years 1937 to 1940. Small numbers of *Ascogaster* and *Glypta* were recovered the third year following liberation and the attack increased steadily from 0·48 per cent in 1941 to 80·1 per cent in 1945. In 1946 there was a marked reduction in pod infestation which appeared to have been due to the high degree of attack by parasites. In 1947 there was a reduction in infestation throughout the area but the reduction was greatest in sections where the parasites were known to be present. Severe floods made it impossible to carry on investigations in the area during 1948, but the effect of the floods on both pest and parasites will be followed with interest in 1949.

The orchard mealy bug of Europe, *Phenacoccus aceris* Sign., occurs in both Nova Scotia and British Columbia. It was discovered in British Columbia in 1913 and by 1935 very damaging infestations were present on apple trees in the Kootenay and Creston areas. It was later found in the Okanagan Valley and on Vancouver Island. In Nova Scotia it was found that a parasite, *Allotropa utilis* Mues., was keeping the pest under control and in 1938 this species was liberated in the most heavily infested areas in British Columbia. It became established immediately and by 1944 its effect on the host population was such that spraying of trees within a radius of several hundred yards of the liberation points was not considered necessary. In the presence of a heavy host population this parasite spreads very slowly so distribution is being hastened by additional liberations at a number of points throughout the Kootenay and Okanagan Valleys and more recently on Vancouver Island.

Control of the greenhouse whitefly, *Trialeurodes vaporariorum* Westw., by the use of the parasite *Encarsia formosa* Gahan. has been of great value to the growers in British Columbia, particularly in connection with the winter and spring production of tomatoes and cucumbers which is an important industry in the province. *Encarsia* was first used in British Columbia in 1934 but unlike most biological control projects this involves frequent recolonization of the parasite due to the methods employed in the handling of greenhouse-grown crops. A stock of *Encarsia* is maintained at the Dominion Parasite Laboratory, Belleville, and growers throughout Canada are furnished with material as requested for the control of this pest.

A very important feature of biological control activities in British Columbia and one which emphasizes the value of the parasite introductions is concerned with the transfer to the Eastern Province of species which have been colonized in the west. Important among these may be mentioned the larch sawfly parasites, *Mesoleius aulicus,* and *Tritneptis klugii,* the satin moth parasite *Apanteles solitarius,* the earwig parasite *Bigonichaeta setipennis* and the peamoth parasites *Ascogaster quadridentatus* and *Glypta haesitator.* Another important development has been the transfer of parasites of native insects from British Columbia to the Eastern Provinces. The most recent work in this direction is the transfer of spruce budworm parasites which was initiated in 1943. During the course of this work several million budworm larvae and pupae have been reared and a total of forty-five species of parasites have emerged. At least six of these have been definitely identified as species which do not occur on the budworm in Eastern Canada and these are being colonized at strategic points in the infested areas as rapidly as possible. At the present time the possible transfer of parasites of the hemlock looper, *Lambdina fiscellaria* (Guen.), is being investigated. There would appear to be many possibilities in this aspect of biological control work by adding to the local parasite population through the transfer of species from other areas within the Dominion.

Prior to 1948 all organized work on biological control in Canada was carried on from various centres in the Eastern Provinces and since 1929 from the Dominion Parasite Laboratory at Belleville, Ontario. Parasites from Europe have been obtained through the Commonwealth Bureau of Biological Control, now with headquarters in

Canada, but from 1927 to 1940 at Farnham Royal, England. During 1948 the Canadian work was reorganized with the headquarters of the Unit located at Ottawa and a laboratory for biological control investigations was established on the campus of the University of British Columbia to serve as a regional headquarters for all work of this nature in British Columbia. The Dominion Parasite Laboratory will remain the centre for introduction and distribution of parasites and predators throughout Canada and due to its special facilities and equipment, will be the chief centre for research and training of personnel. The work of the Vancouver Laboratory will be closely coordinated with the work at Belleville and with the work of other Units of the Division of Entomology in British Columbia. More detailed and exhaustive studies will be carried out in the field than has been possible heretofore and the closer contact with the problems and with others interested in pest control on the Pacific Coast will greatly facilitate the development and expansion of the service being rendered in pest control.

NATURAL CONTROL OF THE CALIFORNIA RED SCALE IN UNTREATED CITRUS ORCHARDS IN SOUTHERN CALIFORNIA[1]

By **Paul DeBach**, **C. A. Fleschner**, **E. J. Dietrick**, Division of Biological Control, University of California Citrus Experiment Station, Riverside, California.[2]

The California red scale, *Aonidiella aurantii* (Mask.), was introduced into southern California, at Los Angeles, in 1878, on six lemon trees imported from Australia. Another introduction from Australia about the same time established the red scale on citrus near Orange, California. The red scale has since become dispersed throughout the citrus areas of southern California and has increased in severity until, with the successful biological control of the black scale in the past decade, it is now the most important insect pest of citrus.

In spite of many attempts by the Division of Biological Control of the University of California to introduce and establish parasites and predators which would successfully control the red scale, no really favourable results have been obtained. At the present time the introduction of new parasites from China is being attempted.

Insecticidal treatments, especially fumigation, were developed early and soon became part of an annual programme for control of the red scale. Later, oil sprays came into prominent usage. Insecticidal treatment on a more or less annual basis has continued up to the present time. With very few exceptions, and these generally based upon isolated observations rather than data, there has been no hint that natural enemies of red scale, or other mortality factors of appreciable importance, exist in southern California.

In past years entomologists have occasionally noted red-scale-infested groves which cleaned up, or which managed to go several years without requiring the usual treatment. These have generally been thought of as exceptions caused by some peculiar combination of atypical conditions. Weather extremes have been commonly thought to be controlling factors. Trees in certain groves have been thought to be resistant to red scale. Predators have occasionally been given credit for control of red scale, and *Aphytis chrysomphali* (Mercet), the only generally established red-scale parasite, has been mentioned once or twice in the literature as a possible factor.

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[1] Paper No. 000, University of California Citrus Experiment Station, Riverside, California.

[2] Mr. T. W. Fisher assisted materially in the later phases of the field counts.

One of the more recent porgrammes of the Division of Biological Control of the University of California has been to acquire detailed ecological information concerning the major pests of citrus. It is hoped that this information will lead to methods of manipulating the environment in such a way that natural control of certain pests may be obtained from the natural mortality factors already present in the field. Such manipulation could take many directions, but a full discussion of this aspect of the problem is outside the scope of the present paper. Briefly, such management might include (1) mass culture and liberation of natural enemies at critical periods, (2) use of alternate host plants to maintain reservoir host populations for natural field insectaries, (3) artificial infestation of plants with (host) pest insects at critical periods to synchronize pest and parasite/predator populations, or, perhaps, (4) a change in treatment or even cessation of treatment for a given pest.

Inasmuch as the red scale is the most important pest of citrus in southern California, ecological field studies were concentrated on this insect, beginning in January, 1948. In order to study the red scale under conditions permitting the scale and its natural mortality factors complete freedom of interaction, one artificial variable, namely, insecticidal treatment, had to be eliminated. Therefore, an attempt was made to find groves in which infestations of red scale had been untreated for some time, or to obtain groves whose owners wanted to cease insecticidal treatments for red scale and would permit us to carry on work for a more or less extended period of time. Since, in California, red-scale-infested groves are considered a hazard to neighbouring groves, treatment may be required by law if judged necessary by the County Agricultural Commissioner. Our groves, therefore, needed to be isolated or otherwise constituted so that close neighbours were not likely to complain and force treatment. The co-operation of the various County Agricultural Commissioners on a general survey of untreated groves enabled us to obtain a few groves in various part of southern California, which fitted into one or the other of the above categories.

Field Plots.—By early spring of 1948, eight red-scale-infested groves had been obtained as study plots. Five of these groves had been untreated for red scale for eight or more years and could be considered to have had ample opportunity for the establishment of a balance between populations of the red scale and its natural mortality factors. Three of the groves had been untreated for one to two years and were thought not to have had time to reach a state of equilibrium. For purposes of the present study, an arbitrary minimum of three years without treatment was deemed necessary before a red-scale-infested grove could be considered to have had sufficient opportunity for the establishment of an equilibrium between the scale and its natural enemies. In 1948 additional untreated red-scale-infested groves were acquired, so that we now have some seventeen orange and lemon groves under experimental study or observation. More groves will no doubt be available as time goes on.

A general description of the present situation may serve for orientation. Detailed data from certain more or less typical untreated groves will then be presented. Dispersed throughout the so-called red-scale citrus areas of southern California are a few red-scale-infested groves which are commercially clean, and which have not been treated for scale for periods of four to ten or more years. That this is not the result of weather is indicated by the fact that adjacent groves are regularly treated for red scale. The groves which are under the most complete natural control, that is, those which have no tree damage and virtually no fruit cullage because of red scale, are orange groves ten or more years old, which are well cared for and as a result are vigorous and heavily foliaged. Although two heavily foliaged lemon groves are known to be under satisfactory natural control, lemons, for the most part, appear to be less susceptible to red-scale control by natural factors. This is thought to be correlated with the generally sparse foliation of lemon trees and the ability of red-scale populations to increase more rapidly on lemons than on oranges. Young orange trees, likewise, seem to be less susceptible to natural control than older orange trees. Indications are that the relative humidity maintained in different sizes or varieties of citrus trees is an important factor affecting natural control.

Of the eight groves known to have had no treatment for red scale for four or more years, two are not commercially clean. One of these, a lemon grove in Orange County, is not well cared for and is sparsely foliaged; the red-scale infestation in this grove is not heavily damaging to the trees, but too large a portion of the fruit would be classed as culls because of the red-scale infestation. The other grove is on the grounds of the Citrus Experiment Station at Riverside. This small grove consists of young citrus trees, including lemon, grapefruit, and Valencia and navel oranges. This grove has not received the best cultural care, foliage is sparse, and red scale is chronically heavy.

Evaluation of Mortality Factors Affecting the California Red Scale.—Methods of evaluating the relative importance of natural mortality factors affecting the red scale in the field were of necessity among our first problems. Obviously, although weather undoubtedly is the cause of considerable red-scale mortality at times, it is not a regulatory factor, since the commercially clean, untreated groves mentioned above coexist with neighbouring groves in which red-scale infestations generally require treatment on an annual basis.

Experimental sleeve-cage comparisons (for technique, see DeBach *et al.*, 1949), as well as insecticidal check tests (DeBach, 1946), confirmed the conclusion that weather did not *regulate* red-scale populations in the areas studied during 1948. By the same token, these tests eliminated the possibility of host-plant resistance as a factor in the plots under experimental study. In short, these experimental methods of evaluating the effectiveness of natural enemies comprise a comparison, in time, between two initially comparable red-scale populations on the same or adjacent trees in a grove. The only difference between these two red-scale populations is that imposed by the tests. Natural enemies are eliminated as a mortality factor affecting one of the paired populations. Growth of the red-scale populations in the two categories, one with natural enemies and one without, gives a striking picture of the effectiveness of the natural enemies. The sleeve cages and the insecticidal check methods complement each other in that, together, they are affected by no factors other than entomophagous enemies. Climate, disease, varietal resistance, and other mortality factors are pretty well ruled out by these tests.

One method involves the use of pairs of organdie sleeve cages (DeBach *et al.*, 1949) placed over branches of citrus trees infested with red scale. One sleeve is left slightly open at both ends so that natural enemies have ready ingress and egress; the other sleeve of the pair (previously impregnated with technical DDT) is closed at both ends (Fig. 1). Natural enemies cannot enter the closed sleeve and those already inside the sleeve soon contact the DDT-impregnated cloth and are eliminated. Because of their nonmigratory habits, the scales are not affected.

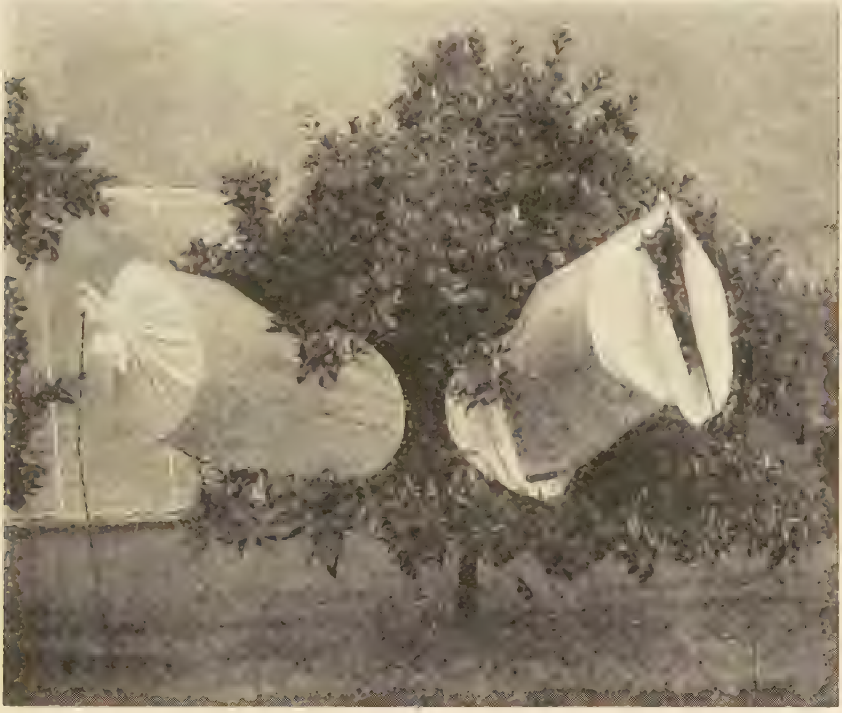

FIG. 1.—Left, closed DDT-impregnated organdie sleeve cage which excludes and eliminates natural enemies. Right, open untreated sleeve cage which permits natural enemies ready ingress and egress.

The other method (DeBach, 1946) involves the treatment of certain trees with a spray-dust application of DDT, which is lethal to active natural enemies but sublethal to sessile red scale. The development of red-scale populations on these trees is compared with that on adjacent, untreated trees.

Another method of evaluation involves the accumulation of periodic census data concerning populations of the red scale and its natural enemies. Correlation of the changes in the host and parasite or predator populations may help interpret the effectiveness of the natural enemies.

Relative Importance of the Various Natural Enemies.—Many natural enemies feed upon the red scale in southern California, but only four appear to merit consideration as factors which might commonly influence red-scale populations. These are the predators *Lindorus lophanthae* (Blaisd.), *Chilocorus stigma* (Say),[3] and *Orcus chalybeus* (Boisd.), and the parasite *Aphytis chrysomphali* (Mercet). *Orcus* is limited to citrus areas immediately adjacent to the coast; the other species are generally distributed. The introduced parasites *Habrolepis rouxi* Compere and *Comperiella bifasciata* Howard are established on red scale but are localized and as yet of no consequence.

In a red-scale-infested grove in which a complex of one or more of the predators and the parasite *Aphytis* occurs, it is extremely difficult to evaluate the relative importance of the species. As it happens, however, a complex of natural enemies occurs only in those groves which are newly untreated and have not had opportunity to establish a natural balance, or in those untreated groves in which for some reason the red scale is not maintained at or below a commercially clean level. In all the groves that we have seen which can be considered to be under good natural control, virtually the only natural enemy operating is the golden chalcid, *Aphytis chrysomphali.* Since *Aphytis* demonstrates in this manner its ability to work in extremely low red-scale population densities, it is apparent that potentially it is by far the most effective natural enemy. The predators, although they may reduce high red-scale densities, have not demonstrated the ability to maintain themselves in the field at red-scale densities which the average grower would consider satisfastorily low.

Evaluation of the Effectiveness of the Parasite Aphytis chrysomphali.—The only factor found to be operating as a regulatory agent against red scale in those groves under excellent natural control was, as stated above, the parasite *Aphytis chrysomphali.* Data from our studies in these groves early in 1948 surprised us, therefore, when they showed parasitization of only approximately 5 to 10 per cent. It was hard to accept this low degree of parasitization as indication of a successful control factor, even though theoretically it might be possible. Indeed, Quayle (1911), on the basis of the same kind of data, stated: "While it is not uncommon to find this parasite on red scale from many sections of the citrus belt, it has never been seen occurring in large numbers. Examination and counts have been made at various times during the past three seasons, and, thus far, we have not found the number of scales parasitized to exceed 10 per cent. This amount of parasitization is, of course, of little value in checking the number of scales."

Inasmuch as our sleeve-cage tests and DDT insecticidal check trees showed that a natural enemy was undoubtedly responsible for keeping the scale low, and since *Aphytis* was the only natural enemy present in the groves under complete natural control, we intensified the study of *Aphytis.* Data were soon acquired which indicated considerable mortality associated with the presence of *Aphytis*, in addition to that caused by parasitism. This pointed to the possibility that *Aphytis* frequently kills scale by insertion of the ovipositor but does not always deposit eggs. Mr. Glenn Finney and Dr. Irma Crouzel had previously noted, in investigations in our laboratory, that *Aphytis* killed scale apparently by mutilation with the ovipositor.

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[3] This may represent a complex of several species or subspecies, including those known as *Chilocorus confusor* Casey, *C. renipustulatus* Scriba, and *C. orbus* Casey.

Earlier studies with the black scale showed that its parasite *Metaphycus helvolus* (Compere) drills a hole in the scale with its ovipositor, then sucks out the body fluid (Flanders, 1941), and, in the field, kills about three times as many scale in this manner as by actual parasitism (DeBach, 1943). Fleschner, following these leads in the laboratory, soon determined that adult *Aphytis* host-feed upon red scale. *Aphytis chrysomphali* forms a feeding tube by means of a waxy secretion which hardens around the ovipositor. The hemolymph of the scale is sucked out through this tube by the adult parasite. Preliminary indications are that host-feeding by *Aphytis* adults may be necessary for oviposition, and that considerably more mortality may be caused by host-feeding than by actual parasitization. In view of this new information, it is not surprising that many past workers have considered *Aphytis* to be a parasite without potentialities.

Field Data on Red Scale and Natural Enemy Populations in 1948.—The development of red-scale populations during 1948 in a typical Valencia orange grove under satisfactory natural control is shown in figure 2. *Aphytis chrysomphali* was the only natural enemy of any consequence in this grove. The percentage of parasitization by *Aphytis* is shown on the same chart.

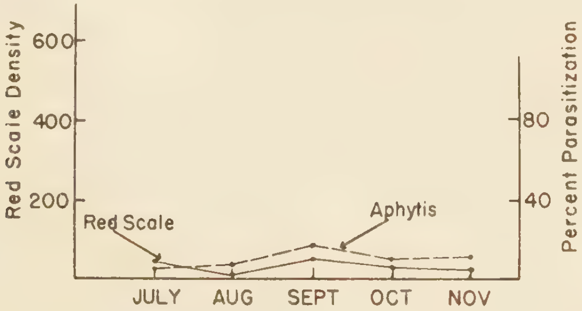

FIG. 2.—Population density of California red scale and percentage of parasitization by *Aphytis chrysomphali* in the Walker Valencia orange grove, El Toro, Orange County, California, 1948.

Mortality of red scale due to host-feeding by adult *Aphytis* has not been measured by the sampling method employed in securing the data graphed in figure 2; therefore, the relation between *Aphytis*-caused mortality and changes in the red-scale population is obscure. It is apparent, however, that a constant parasitization of 10 to 20 per cent is capable of maintaining red-scale populations at a low steady density. The density of red scale in this grove was very low, being between 10 and 50 (Fig. 2). These densities represent the total number of live scales on a standard sample consisting of 24 twigs from each of 10 trees.

Data from experimental tests in the same grove, showing changes in the red-scale population in the presence and absence of *Aphytis,* are more conclusive. Figure 3 shows typical examples of changes in the red-scale infestation in sleeve-cage tests over an 8-month period (March 26 to December 1, 1948) in the presence (in open sleeves) and absence (in closed, DDT-impregnated sleeves) of *Aphytis*. Obviously, *Aphytis* maintained an excellent degree of control.

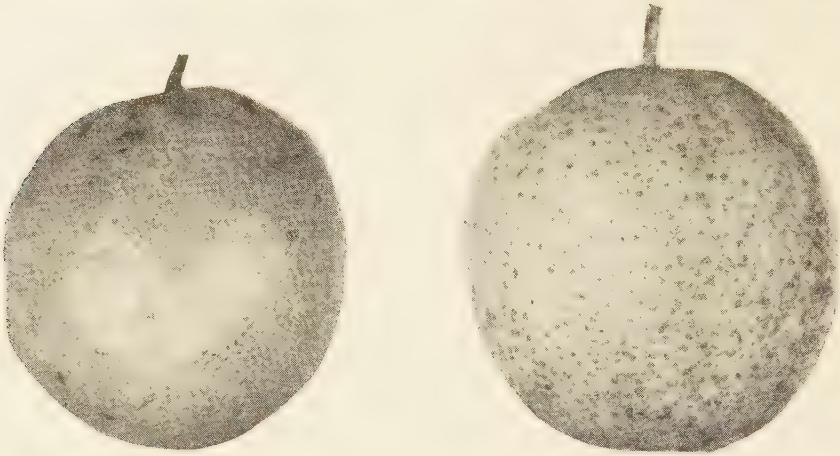

FIG. 3.—Left, typical fruit from an untreated open sleeve cage, showing the result of natural control of California red scale by the parasite *Aphytis chrysomphali.* Right, typical fruit from a DDT-treated closed sleeve cage, showing the population density of red scale which would have occurred generally on fruit in the same grove by the end of the period April to December, 1948, in the absence of the parasite. (Walker Valencia orange grove, El Toro, Orange County, California.)

Data in Table 1, from the same grove, show the relative increase in red scale over a 5-month period (July 28, 1948, to January 6, 1949) in the presence and absence of *Aphytis,* as measured by the DDT-insecticidal check tests. The DDT-spray-dusting of trees eliminated *Aphytis* and permitted the scale to increase. *Aphytis* worked normally on the untreated check trees. The difference is marked in spite of the fact

TABLE I.—Relative increase in initially comparable populations of California red scale, over a 5-month period (July 28, 1948, to January 6, 1949), on trees spray-dusted with DDT (parasite *Aphytis chrysomphali* absent) and on untreated trees (parasite present).

RED-SCALE POPULATION[1]

Final Rating[2]	Trees Spray-Dusted with DDT (parasite absent)	Untreated Trees (parasite present)	Ratio, Treated to Untreated
On twigs	242	16	15·1
On fruits	15,744	1,872	8·4

[1] Red-scale population on treated trees, medium-heavy; on untreated trees, very light.

[2] Fruit and twig ratings were taken in different ways and do not necessarily indicate relative densities of red-scale populations on twigs and fruits.

that the periodic monthly renewal of the very light DDT application resulted in considerable mortality to newly hatched and newly settled red scales. This supplements the previous data concerning the effectiveness of *Aphytis*.

Certain groves previously discussed are not in that condition known to the industry as "commercially clean", as far as red scale is concerned. Some of these groves have not, as yet, been untreated for a long-enough period to have attained a balance between the red scale and its natural enemies; others, for one reason or another, do not furnish a suitable environment for *Aphytis*. It is in such groves that predators tend to assume a major role. Predators (*Lindorus, Chilocorus, Orcus*) apparently do regulate populations of the red scale, but only within limits which are generally above the point of economic damage. Predators may or may not prevent the occurrence of serious damage to the tree by red scale. Normally, predators do not become a factor until red-scale populations are more or less heavy; they may then build up and greatly reduce the scale populations. Such a phenomenon, however, virtually eliminates the predators from the particular infestation, and the cycle starts anew.

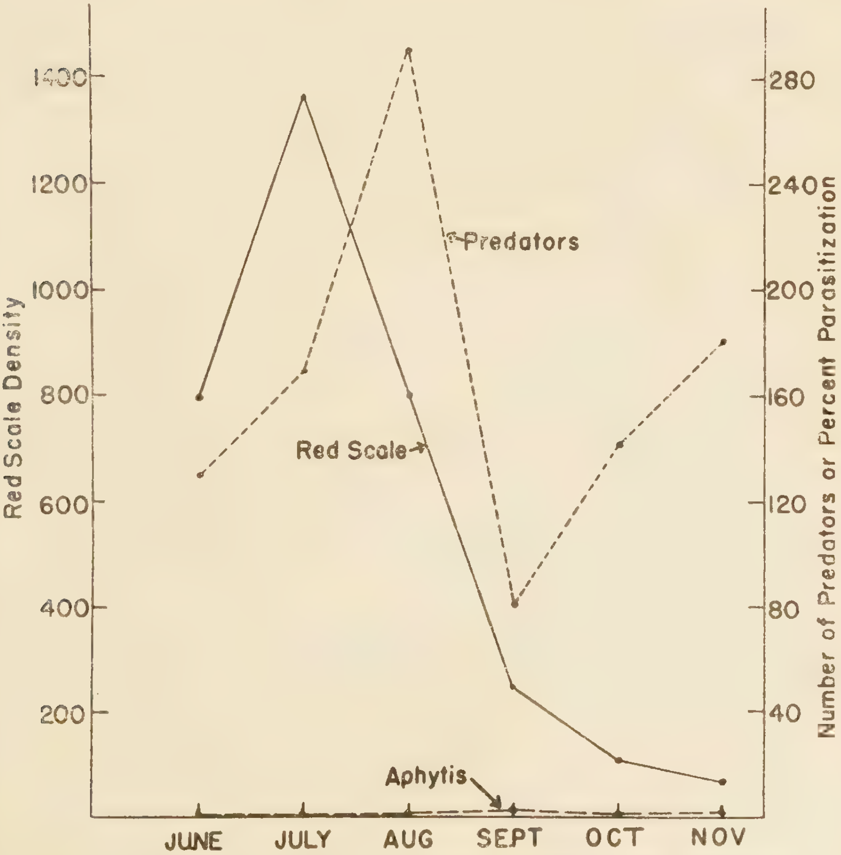

FIG. 4.–California red scale and predator populations and percentage of parasitization of the red scale by *Aphytis chrysomphali* in the McNair lemon grove, El Cajon, San Diego County, California, 1948.

Figure 4 depicts graphically a typical red scale–predator relationship in a lemon grove which was in its second year of nontreatment. Note that the average red-scale population is much higher in this lemon grove than in the orange grove of figure 2, which represents the red scale and its parasite *Aphytis*. In general, predators are found to occur in any numbers only when the red-scale rating is above 200 (see scale density, Figs. 2 and 4). This represents, at the minimum, a commercially light infestation. Sleeve-cage tests in this lemon grove indicated that the trees would have been defoliated and virtually killed by the fall of 1948 had predators been absent. It is of interest that *Aphytis* maintained itself in this grove but did not exceed 2 per cent parasitization during the 1948 season. These lemon trees were sparsely foliaged. Orange trees grown adjacent to these lemons by the same grower and with the same past cultural history had a much lower red-scale population (Fig. 5). *Aphytis* was common on the orange trees, and predators were practically nonexistent, even though common on the lemon trees 100 feet away. Red-scale populations in this range are evidently too low to attract and maintain predators. Apparently, *Aphytis* brought about a satisfactory state of balance in this orange block within two years after the cessation of treatment.

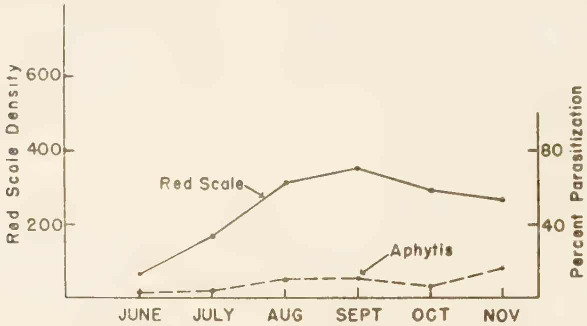

FIG. 5.—Population density of California red scale and percentage of parasitization by *Aphytis chrysomphali* in the McNair orange grove, El Cajon, San Diego County, California, 1948.

Discussion and Conclusions.—The California red scale, *Aonidiella aurantii* (Mask.), is a serious pest of citrus in certain parts of the world, and not in others. In the past this variation has generally been attributed to the influence of climatic factors. A list of countries in which red scale is an important pest of citrus, and of countries in which it is generally distributed but is a minor pest, or not a pest at all, on citrus, is given in Table 2.

No distinct climate seems to be associated with the natural control of red scale. Evidence (Table 2) might seem to point to the develop-

TABLE 2.—Relative importance of California red scale as a pest of citrus in various countries.

Major Pest	Minor Pest	Not a Pest
Australia	Cyprus	Brazil
California, U.S.A.	Palestine	China
Northwest Mexico	Rhodes	Egypt
South Africa	Western Australia	Florida, U.S.A.
		India
		Italy
		North Africa
		Paraguay
		Spain
		Texas, U.S.A.

ment of red scale as a serious pest exclusively in the more arid climates, but this is contradicted by its unimportance in Spain, Italy, and North Africa. The possibility remains that it is the effect of climate on natural enemies, especially on *Aphytis*, that is most responsible for the degree of pest status attained by red scale in any given country.

At yet, there has been no detailed ecological study of *Aphytis chrysomphali* as a parasite of California red scale in any country. This is emphasized by the fact that host-feeding by the adult parasite has hitherto been unknown. Extensive observation of the parasite (*Aphytis chrysomphali*)--red scale complex has been made throughout the world, with the result that some entomologists, even though ignorant of the red-scale mortality caused by host-feeding of adult *Aphytis*, have considered *Aphytis* to be an important, if not constantly reliable, control factor.

In Western Australia, the California red scale was the worst pest of citrus up to 1907. It is now at least partly under biological control. In November, 1905, George Compere landed in Perth, from China, with red scale parasitized by *Aphytis*. These parasites were reared in a cage and liberated in various parts of the state in May, 1906. Newman (1928) reported that "In most years this scale is well controlled by the internal parasite *Aphelinus [Aphytis] chrysomphalus*," and Jenkins (1945) says: "It *[Aphytis chrysomphali]* is widely established locally and in some districts plays a part in keeping the scale population within reasonable bounds."

In Palestine, Carmin & Scheinkin (1934) concluded that "It is very doubtful if climatic conditions have to do much directly in our country with the control of *Aonidiella* . . . Predators seem to have little effect on the control of *Aonidiella* . . . *Aonidiella* seems to be biologically controlled in Palestine, the main exterminating agents being *Aphytis chrysomphali* Mercet and different fungi . . . *Aphytis chrysomphali* Mercet was found to parasitize some 50 per cent of the brood of November-May . . ." Hall & Ford (1933) expressed the opinion that *Aphytis chrysomphali* exercises some control over red scale on citrus in southern Rhodesia. Woglum *et al.* (1947), referring to the days in southern California before insecticidal treatment was as intensive and extensive as at present, state that "*Aphytis chrysomphali* (Mercet) could be found actively at work in every orchard infested with red scale, in fact, not infrequently accomplishing very good commercial control." In those countries in which red scale is present but is not a problem, no real information exists as to the roles played by the various natural factors.

The world situation as a whole, with regard to the relation between the red scale and its parasite, *Aphytis*, seems to resemble the condition in southern California: climate does not seem to be directly responsible for regulating red-scale population densities within the citrus areas; red scale is an important and general pest but in certain areas it is under a degree of natural control; this control is attributed by various workers to *Aphytis chrysomphali.*

The question that immediately comes to mind is this: If, as stated, local variation in climate in southern California is not a regulatory factor in certain groves under natural control, and if *Aphytis* is the controlling factor, why is it that only a few groves are kept commercially clean of red scale by the action of *Aphytis*, whereas most groves infested with red scale apparently must receive regular treatment? The answer is not simple, and at the presnt time can only be deduced.

To begin with, *Aphytis chrysomphali,* although capable of maintaining red-scale populations below the point of economic damage, evidently is not so efficient a parasite as the best we have found on certain other pests, namely, parasites such as *Coccophagus gurneyi* Compere and *Tetracnemus pretiosus* Timb., parasitic on the citrophilus mealybug (*Pseudococcus gahani* Green), or such as *Metaphycus helvolus,* parasitic on the black scale (*Saissetia oleae* [Bern.]). *Aphytis* operates at a somewhat higher host density than these parasites; therefore, if other factors interfere with *Aphytis,* the red scale may develop beyond the economic zero level fairly rapidly. Obviously, periodic insecticidal treatment is one factor which will upset *Aphytis,* either directly, by killing a large proportion of the parasites, or indirectly, by killing a large proportion of the host and thus causing the parasites to migrate or die out because of host scarcity.

Since insecticidal treatment for red scale started as soon as red scale was found in southern California, and expanded and spread as red scale spread, this one factor constituted a major difficulty in the way of the general establishment of a natural balance between host and parasite. Once a grove was treated, probably only in a rare instance could *Aphytis* bring about a natural balance without that grove first going through a period of high red-scale density. This would naturally follow in a treated grove, because *Aphytis* would be scarce or nonexistent following treatment and the red scale would increase relatively unhindered. The grower seeing such a build-up of red scale would conclude, as did Woglum (1949), that "In fact, the way red scale is able to increase now from a seemingly light infestation to highly destructive proportions within a few months is sufficient evidence to citrus growers that the only known successful way to cope with red scale and protect the trees and fruit is by prompt and energetic action with the fumigation tent or spray machine." At the present time growers and pest control operators are taught that treatment is frequently applied as an insurance measure rather than out of actual necessity. Furthermore, even though an individual grower might wish to let his grove go untreated in an attempt to secure natural control, treatment for red scale can be required of a grower by the County Agricultural Commissioner if he deems such treatment necessary to protect neighbouring groves.

Certain natural abiotic factors may also be detrimental to *Aphytis* populations. Preliminary evidence indicates that populations of *Aphytis chrysomphali* may be adversely affected by climatic extremes, especially by periods of low humidity or unusually low temperatures. High temperatures may also be important. These climatic factors are undoubtedly tied in with the amount of shelter and protection afforded by the tree.

Ants are also a factor inhibiting the effectiveness of both the parasite *Aphytis* and the predators attacking red scale. The ants, most commonly the Argentine ant, are primarily engaged in tending mealybugs and unarmoured scales for the honeydew they produce. Secondarily, however, the ants interfere with and frequently attack any natural enemies which they contact. Trees in untreated groves attended by ants have heavier red-scale infestations than trees free from ants. Ants have been eliminated experimentally from red-scale-infested trees with a subsequent reduction in red-scale populations. Results of such a test are shown in Table 3.

TABLE 3.—Populations of California red scale and of citrus mealybugs on lemon trees on which ants were abundant (trees untreated) or absent (trees treated), 1948.[1]

	October		November		December	
Ants	Red Scale	Mealybugs	Red Scale	Mealybugs	Red Scale	Mealybugs
None	7·2	0·0	5·7	0·0	8·0	0·7
Abundant	22·8	20·0	39·8	29·0	27·2	20·5

[1] Ants were eliminated from trees on July 8, 1948, by application of 5 per cent chlordan dust around bask of trunk. No other access to trees was available to ants. Average initial populations of red scale and of mealybugs were similar on treated trees (ants eliminated) and on untreated trees.

When all these things are considered together, it is not surprising that *Aphytis* fails to maintain the red scale in a state of natural balance below economic levels throughout most of the citrus acreage in southern California.

The fact that *Aphytis* is controlling red scale in any groves is the real surprise. The groves under natural control probably represent a fortunate combination of circumstances. Several are isolated, and this has alleviated the situation as far as forcing of treatment by neighbours is concerned. The vigorous condition of the trees and foliage has undoubtedly been a factor favouring *Aphytis* in the groves under the best natural control. The owners of certain of these orchards are averse to insecticidal treatment. As a result, they may have, at one time or another, put up with red-scale infestation which most growers would deem necessary to treat. It goes without saying, of course, that the groves under natural control are in districts favourable to *Aphytis*. Environmental resistance to *Aphytis* may be greater in other districts.

Another question automatically arises at this point: Can the factors adversely affecting *Aphytis* populations be changed or manipulated in some way in order to bring more groves under natural control? Our current studies are primarily concerned with the development of this aspect. They involve the determination of those factors which adversely affect *Aphytis* in the field, as well as the effect to be obtained from liberations of *Aphytis* adults in large numbers at critical periods. We hope that as a result of these studies it will be possible to increase materially the amount of red-scale-infested citrus acreage under natural control.

Summary.—Although the California red scale, *Aonidiella aurantii* (Mask.), is the citrus pest of greatest economic importance in southern California, it is satisfactorily controlled by natural factors in certain *untreated* citrus groves. Orange groves appear more susceptible to natural control than lemon groves, but examples of lemon groves under natural control are known. Large, vigorous, heavily foliaged trees are most amenable to natural control. Young, sparsely foliaged trees constitute a more favourable environment for the red scale and a less favourable one for the natural enemies. Annual insecticidal treatment for red scale probably precludes the possibility of attaining satisfactory natural balance.

Experimental comparisons demonstrate that, in groves under natural control, the elimination of natural enemies results in a rapid increase in population density of the red scale. In the groves studied, climate, disease, and varietal resistance were not factors regulating California red scale populations.

The golden chalcid, *Aphytis chrysomphali* (Mercet), is by far the most important natural enemy attacking the red scale. It is the only one capable of maintaining a balance at very low red-scale population densities. The degree of parasitization by *Aphytis* is generally low (approximately 10 to 20 per cent) at any given time. Formerly, this led to the belief that *Aphytis* was not an efficient parasite. Host-feeding by the adult parasite was found to be an important cause of host mortality; this helps explain how *Aphytis* can maintain red-scale populations at a low density and yet not exhibit a high degree of parasitization.

The predators *Lindorus lophanthae* (Blaisd.), *Chilocorus* spp., and *Orcus chalybeus* (Boisd.) commonly become abundant in heavy red-scale infestations. The predators may succeed in protecting the tree from excessive damage or death from red-scale infestations, but they do not maintain scale populations at a density low enough to be satisfactory to the growers.

Indications are that *Aphytis* may be adversely affected, in comparison with red scale, by climatic extremes. Low humidity appears to be of especial importance. Liberation of *Aphytis* adults in large numbers following a critical period may succeed in maintaining a satisfactory degree of natural control of red scale in districts in which the climate is periodically unfavourable to *Aphytis*.

Ants inhibit the work of both the parasite *Aphytis* and the predators of red scale.

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Discussion

Pemberton (Hawaii) commented on the importance of mortality produced by adult parasites feeding on the hosts instancing *Scolia manilae* on *Anomala* in Hawaii.

O'Connor (Fiji) commented on biological races of parasites with reference to coconut scale.

POPULATION STUDIES OF THE LONG-TAILED MEALYBUG AND ITS NATURAL ENEMIES ON CITRUS TREES IN SOUTHERN CALIFORNIA, 1947

By Paul DeBach, C. A. Fleschner, E. J. Dietrick, Division of Biological Control, University of California Citrus Experiment Station, Riverside, California

[*Abstract*]

Field population studies of the long-tailed mealybug *Pseudococcus longispinus* on citrus trees in southern California during 1947 revealed that natural enemies invariably control and reduce the spring increase of mealybugs by midsummer. A complex of predators and parasites brings about this control and the relative efficiency of each is discussed.

The effect of hyperparasites and parasites of the predators on the efficiency of control of the mealybug is considered. Differences in population trends as shown by data obtained from these studies and data obtained from studies made during 1946 in the same general area are analyzed.

Discussion

Discussion followed by Miller (New Zealand) and Smith (California) on mealybugs in New Zealand in relation to parasites.

OBSERVATIONS ON THE LIFE HISTORY OF THE MARIANA COCONUT BEETLE, *BRONTISPA MARIANA* SPAETH, AND THE INTRODUCTION OF PARASITES FOR ITS CONTROL

By W. Harry Lange, Jr., University of California

According to Esaki (1940) the hispid beetle, *Brontispa mariana* Spaeth, (called in his paper *Plarispa castaneipennis* Chujo) was first discovered on Saipan in 1931 and during the period 1935-36 the plantations were fatally damaged. The infested area included 70 per cent of the plantations, and was burned over in 1936 by order of the administration. He also included Rota, Yap, and Truk in its distribution. The beetle was collected from Saipan in 1936 and named by Spaeth in 1937. Its wide distribution in the Carolines would suggest that it could have been brought to Saipan or Rota on coconut seedlings. At the present time it is causing severe damage to coconut palms on Saipan, Rota, and perhaps certain of the Caroline Islands.

The reports by Townes and Oakley (1946) based on their survey for the U.S. Commercial Company pointed out the severe damage by the beetle on Saipan and Rota and suggested either eradication of the coconut trees or the introduction of natural enemies. The recommendations for this research were contained in the reply of Knowles A. Ryerson, chairman of the Pacific Science Board, to Admiral Chester W. Nimitz, dated 7 July, 1947. Actual work began October 14 on Saipan. During the period November 19, 1947, to February 6, 1948, a search was made for parasites in the Philippines, Malaya, and Java, and several were introduced to Saipan. The period up to April 5, 1948, was spent on Saipan with visits to Tinian and Rota.

The centre of distribution for the genus *Brontispa* is the Austro-Malayan region. One species, *B. longissima* has seven subspecies distributed on New Guinea, the Solomons, Java, Celebes, Lord Howe Island, Witu Islands, Ceram, and Aru Island. In addition, one species occurs in Dutch New Guinea, one in Mauritius, four in the Philippines, one in Java, one in the Rodriquez Islands, and one in Samoa. *B. mariana* occurs on Saipan, Rota, Anatahan, Ponape, Kusaie, Truk, Ulithi, Yap, Hall Island, Nukuoro, Woleai, and perhaps others, and two other species, *B. chalybeipennis* Zacher and *B. namorikia* Maulik, occur on certain of the Carolines, Palaus, and Marshalls.

The adult beetle is greatly flattened, approximately 8-9 mm. long by 2-2·5 mm. wide, and of a glossy, dark brown colour. The male is usually smaller and has a longer, bluntly terminating interantennal projection.

The eggs are laid in seed-like capsules, flattened dorso-ventrally, with shallow hexagonal reticulations, and are approximately 0·75 mm. wide by 1·5 mm. long. They are laid between the folded leaflets, inter- or intra-pinnately. The adults prefer the younger, more tightly folded leaves as a place for oviposition. The eggs are usually laid singly or in pairs end to end, but can ocasionally be laid in groups of from 3 to 6, all end to end. The egg is lightly glued to the surface of the leaf and the female beetle places a blob of grass or chewed-up leaf epidermis on each end of the egg or group of eggs.

The larvae emerge through a slit made at one end of the egg, usually by means of the posterior hooks. They moult three times, or have four larval instars. The larvae feed on the outside or inside of the leaves making longitudinal feeding lines which often run together and in a short time the entire leaf area becomes discoloured. There is usually a short, inactive prepupal state, then the larva pupates nakedly. The pupae usually occur near the base of the leaflets on the inside, and are easily dislodged and fall out when the leaves are disturbed. They are capable of limited movement.

The life history of the beetle was studied in the laboratory on Saipan. It was found possible to rear the different stages in stendor dishes. Larvae were fed pieces of coconut leaf and new food added daily. The temperature in the laboratory varied from 85° F. to 91° F.

The egg stage lasted six days in practically all instances, although occasionally an egg would hatch in five days.

The mean number of days for the larval period was 22·72, with means for each instar as follows: first instar, 4·86 days; second instar, 3·38 days; third instar, 5·05 days; fourth instar, 9·43 days. The variation in the duration of each instar was as follows: first instar, 3-8 days; second instar, 2-7 days; third instar, 2-8 days; fourth instar, 6-16 days.

Usually several days before pupation the larvae remained quiescent. The pupal period varied from 3 to 6 days with a mean of 5·14 days.

Of a total of 33 individual rearings only seven were successfully completed. These varied from 30 to 36 days with a mean of 32·71 days. An average of all records, complete and incomplete, raised this figure to a mean of 33·86 days for the complete life cycle of the beetle.

The adults apparently live for several months. One female started laying eggs on October 21, 1947, and died on December 22, having laid 113 eggs, or an average of 1·88 eggs per day for the 60-day period. Another female laid 106 eggs in 33 days, or an average of 3·21 eggs per day.

Generations of the beetle in the field could not be differentiated, although there was definitely a cyclic development on a particular tree. Often it was necessary, for example, to examine three to six trees before one could be found having enough mature larvae or pupae to warrant the liberation of parasites. Continuous generations seemed to occur, and the longer life of the adults usually resulted in an accumulation of hundreds of adults on a single tree.

The adults are positively thigmotropic and negatively phototropic. For this reason it was apparent that adults do not move readily from tree to tree. In fact in the laboratory they were content to remain on small trees as long as a favourable food supply was present. The adults were observed to fly short distances. The larvae are semi-gregarious and tend to feed together on a leaf surface. They can consume a tremendous amount of leaf surface in a short time.

The adult beetles and the larvae cause the characteristic damage. The leaf tissues of the upper or lower surfaces of the leaves are scarred longitudinally as they feed in a straight line leaving the fibres of the leaves. The scarred areas run together leaving large brown, discoloured areas. The larvae and beetles feed almost entirely on the inter-folded leaves before they unfold. The discoloured areas as the leaves unfold are devoid of chlorophyll; the areas dry and become brittle, and the weather and secondary feeding of tineid caterpillars and other insects gives the leaves a weather beaten appearance.

A survey on Saipan during October and November, 1947, indicated that only 32 per cent of the palms were bearing nuts and most of these were not bearing sizeable clusters. On Rota severe damage was noted, although probably less than 1,000 trees remain.

The only known host plant of *B. mariana* in the field is the coconut palm. In the laboratory it was found that both adults and larvae had a decided aversion for Chinese betel nut, *Areca catechu*, although in one instance a mature larva was able to complete its development. Another palmate-leaved palm, probably a *Eupritchardia* sp., growing in the Agricultural Station at Saipan, presumably brought from Guam, was selected by the larvae and adults. Judging from other related hispids, it would be assumed that certain other palms could be selected by this beetle.

The search for parasites began in the Philippines with a one week search in the vicinity of Los Banos. Two hispids were found feeding in a manner similar to *B. mariana*, and one leaf-mining form. On young coconut trees damage of the two-coloured coconut leaf beetle, *Plesispa reichei* was common, but only a few larvae were found. This beetle preferred leaves partially unfolded and the characteristic darkened blemishes on the outside of the leaves persisted. A *Brontispa* sp. was found on the palm *Arenga pinnata*. Although all stages of the beetles were found there was no evidence of parasitism. An infestation of a leaf-mining hispid, *Promecotheca cumingi* was observed and an examination of eggs indicated an 80 per cent parasitism. Dr. Uichanco reported the presence of two egg parasites on *Promecotheca cumingi* namely, *Centrodora* sp., and *Achrysocharis promecothecae* Ferriere, and two larval parasites, *Pleurotropis* sp. and *Sympiesis* sp.

In Malaya, headquarters were established at Kuala Lumpur and a search was begun on all types of palms. No definite records of parasites were available although Corbett (1923) reported the presence of a chalcid egg parasite of *Plesispa reichei*. The genus *Brontispa* is not found in Malaya, and for this reason the search was made primarily on *Plesispa* spp., *Wallacea* spp., and *Wallaceana* spp. Both *Plesispa reichei* and *Plesispa nipa* feed similarly to *B. mariana*, the former on coconut and other palms, the latter on palms of several genera.

Several parasites were reared from hispids in Malaya. The first one collected, an *Achrysocharis* sp., was found to emerge through mature larvae of *Wallacea palmarum* on *Areca catechu*. In one locality, about 10 to 15 per cent of the larvae were parasitized and 6 to 32 adults emerged from a single larva. In one instance the same species was reared from *Plesispa nipa* on nipa palm.

The commonest parasite in Malaya was an egg parasite, *Haeckeliana brontispae* Ferr., recorded before only from Java. In the low area near Klang, approximately 60 per cent of the eggs of *Plesispa nipa* were parasitized by this species. The eggs of this hispid are laid in a group and create excellent conditions for the "build-up" of egg parasites. Adults of this species were successfully introduced to Saipan, and were found to oviposit in the eggs of *B. mariana* and adults were reared in the laboratory. One parasite to an egg emerged.

Another parasite, *Tetrastichus brontispae* (Ferr.) (placed in the genus *Tetrastichodes* by some workers) known previously from Java, was found emerging through pupae, and occasionally mature larvae, of *Plesispa nipa* in several Malayan localities. From 8 to 20 or more parasites emerge from a single larva or pupa. One shipment of parasitized pupae was made to Saipan of this species from Malaya.

An egg parasite, *Ooencyrtus podontiae* Gahan, was found parasitizing 10 to 61 per cent of eggs of *Plesispa reichei* on coconut. This parasite was not introduced due to the small numbers obtained. One parasite to an egg was reared.

In addition to these mentioned, several other parasites were taken from single collections. While in Malaya it was learned that the Institute of Plant Diseases and Insects at Buitenzorg, Java, under Dr. van der Vecht, had reared *Tetrastichus brontispae* for shipment to Celebes before the war. This parasite in Java parasitizes *Brontispa longissima javana* and *selebensis*. Apparently *selebensis* was introduced to Java and occurs with *javana* even on the same tree. This parasite selects pupae in preference to larvae, and pupae under three days old are necessary. In the field in Java it is felt that this parasite together with the egg parasite, *Haeckeliana brontispae*, is partially responsible for keeping *Brontispa* in check. Awibowo (1935) and Lever (1937) mention the introduction of this parasite to the Celebes and the British Solomon Islands.

The method of rearing *Tetrastichus brontispae* in the laboratory is of some interest. One to two day old pupae of *Brontispa* are exposed to the parasites in glass tubes using 15 *Brontispa* pupae to 15 to 24 adult female parasites which had been previously fed a 50-50 water-honey mixture and mated. An exposure of 24 hours was given after which the pupae were removed. Parasites emerged in 18 days. As the pupal period of the beetle is five to six days, the degree of parasitism can be recorded at this time. During overcast weather a low voltage incandescent lamp is used in the rearing chamber to assist in stimulating egg deposition. A total of 572 parasitized pupae were secured in Java and were taken personally to Saipan along with a few egg parasites from Java. A few of the *Tetrastichus* parasites emerging at Kuala Lumpur were tried on pupae of *Plesispa reichei* and were found to readily select this hispid.

On Saipan both *Haeckeliana brontispae* and *Tetrastichus brontispae* were found to select the eggs and pupae respectively of *B. mariana* with little difficulty, and *Tetrastichus* parasites were reared on this beetle and liberated. A few egg parasites were reared from eggs of *B. mariana*, and experiments in the laboratory were conducted with the egg parasite from Java.

Parasitized pupae of *B. mariana* were found in the field on three occasions during this project, namely on February 28, March 11 and 19 respectively, although it was not determined if the parasite was able to successfully establish itself for consecutive generations at this time. On one occasion eggs of *B. mariana* in the field were found to contain dead parasites of *Haeckeliana*.

Approximately 4,000 adults of *Tetrastichus brontispae* were liberated on Saipan and several hundred on Rota during the six-month period of this project. In addition, over 300 adults of the egg parasite were liberated on Saipan and Rota. The parasites were fed and mated in the laboratory and then liberated the same day in the crowns of the coconut trees. An examination was made of each tree to determine the presence of pupae before liberations were made. Usually one to three trees in a locality were infested, depending upon the number of available parasites. On Saipan liberations were made in almost all of the major coconut growing areas, and in several instances repeated liberations were made in the same trees to try and overcome the cyclic condition of generations of the beetle on individual trees.

The reports of the establishment of one of the parasites, namely the eulophid *Tetrastichus brontispae* (Ferr.) are encouraging. Doutt[1] reported the presence of this parasite in six of seven localities examined. In the six localities the parasitism of pupae ranged from approximately 5 to 86 per cent with an average per cent parasitism of 21 per cent. Inasmuch as an attempt was made not to examine the exact trees in the areas where liberations were originally made it becomes apparent that the parasite has undergone some natural dispersion. Doutt also examined 1,374 eggs at eight release points and found no evidence of the establishment of the egg parasite, *Haeckeliana brontispae* Ferr.

SUMMARY

The hispid beetle, *Brontispa mariana* Spaeth, was first discovered on Saipan in 1931, damaging coconut palms. In 1935-36, the Japanese ordered the trees destroyed, and it is estimated that 70 per cent of

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[1] Report to Pacific Science Board dated August 10, 1948.

the trees were killed at this time. The beetle was collected in 1936 and described by Spaeth in 1937. The present investigation was made at the request of the U.S. Navy to the National Research Council and extended from October, 1947, to the end of March, 1948. The centre for distribution of the genus *Brontispa* is in the Austro-Malayan region. *Brontispa mariana* Spaeth is found on certain of the Mariana and Caroline Islands. In the Marianas it does severe damage to coconut palms on Saipan and Rota, and occurs on Anatahan. It has a wide distribution in the Carolines where it also damages coconut palms, but usually to a lesser extent than in the Marianas. The beetles are small, glossy, brown in colour. The eggs are laid in seed-like capsules externally among the interfolded leaves of the palm crowns. The larvae have characteristic terminal hooks, and moult three times, thus having four instars. Pupation occurs nakedly. The adults and larvae cause the damage by feeding on the leaf tissues of the young leaves. These areas turn brown and the leaves as they emerge appear weather beaten. The egg stage lasts six days, the mean larval period lasts 22·7 days, and the pupal period three to six days. The mean number of days for the complete life cycle is 33·86 days in the laboratory at Saipan. The adults are positively thigmotropic and negatively phototropic. A survey on Saipan during November, 1947, indicated only 32 per cent of the trees bearing nuts. The coconut palm is the chief host plant of the beetle, although one larva was reared on *Areca catechu*, and could be reared in the laboratory on a *Eupritchardia* sp. A search for parasites was made in the vicinity of Los Banos in the Philippines, and although several hispid beetles were found, no parasitism was indicated for the types feeding externally. In Malaya several parasites were reared from hispids. The eulophid, *Tetrastichus brontispae* (Ferr.) was found parasitizing pupae of *Plesispa nipa*. An egg parasite, *Haeckeliana* was common on the same beetle. An *Achrysocharis* sp. was found parasitizing mature larvae of *Wallacea palmarum*. The egg parasite *Ooencyrtus podontiae* Gahan was found parasitizing eggs of *Plesispa reichei*. Several other parasites were recovered from individual rearings in Malaya. Two of these, the egg parasite, *Haeckeliana*, and the pupal parasite, *Tetrastichus*, were successfully introduced to Saipan. In Java additional material of *Tetrastichus* and *Haeckeliana* were secured, and arrangements made for later shipments. Approximately 4,000 adult *Tetrastichus* parasites were liberated on Saipan and Rota and 300 egg parasites. A recent survey indicated that the pupal parasite, *Tetrastichus*, had become established at six of seven release points with a range of parasitized pupae of from 5 to 87 per cent, or an average of 21 per cent parasitism. The egg parasite, *Haeckeliana*, was not recovered on Saipan, and it would appear that it did not become established.

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Discussion

O'Connor (Fiji) commented on experience in Fiji and the Solomons with parasites of related species.

ARTIFICIAL INFESTATION OF PLANTS WITH PEST INSECTS AS AN AID IN BIOLOGICAL CONTROL

By Harry S. Smith and Paul DeBach,[1] Division of Biological Control, University of California

Synchronization of populations of an entomophagous insect and its host is frequently disturbed or lacking in nature. When such asynchronization occurs in a species which otherwise would be under satisfactory biological control, oscillations in population density increase markedly in magnitude. This may result in the host insect assuming pest proportions.

Periodic unavailability of hosts is the major cause of upsets in synchronization. This unavailability of hosts may be due either to the low numerical status of the species or to the absence over long periods of susceptible host stages.

Catastrophic factors, such as climatic extremes, disease epidemics or artificial control measures, commonly resulting in more or less prolonged periods of host scarcity, tend generally to bring about a uniformity of developmental stages. If such stages are not suitable for attack, this will be equivalent to the absence of hosts. Obviously, the absence or general scarcity of the host species or of stages suitable for attack will result in a major depression of the population of the entomophagous insect.

Theoretically it would appear possible, therefore, that when hosts are abnormally scarce artificial infestation of plants in the field with the host insect would serve to synchronize parasite-host or predator-prey populations in such a way as to bring about effective biological control. Tests of such a possibility are reported in the present paper. A necessary prerequisite, of course, in any attempt of this sort is the presence of efficient enemies in the complex under consideration.

Ecological factors in southern California may vary tremendously within a matter of a few miles. Thus, an insect pest which may be under effective biological control in one section may be less effectively controlled in another. Such is the case with the black scale, *Saissetia oleae* (Bern.). In coastal areas, a rather even, mild climate results in an overlapping of generations so that all stages of black scale are generally present throughout the year, and the scale is kept at a low density by continually developing generations of the parasite *Metaphycus helvolus* Comp. In interior areas, however, climatic extremes limit the black scale to a single annual generation. This situation results in a great reduction of hosts suitable for parasitism by *M. helvolus* for over three months of the year. Smith (1942) points out that this may result in near elimination, during the summer, of *M. helvolus* from interior orchards but with the approach of fall when the scale become large enough to be successfully parasitized, field liberations of insectary-reared parasites might solve the problem.

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[1] E. J. Dietrick materially assisted in making field counts during 1947.

Another method of approach has been tried previously by other members of this Division. Compere in the early 1920's artificially infested with black scale nightshade plants, growing in citrus groves, in an attempt to synchronize *Metaphycus lounsburyi* with the black scale. Flanders in 1945 planted fifteen oleanders on the windward side of a small citrus grove in order to provide conditions favourable for uneven development of black scale on citrus.

A somewhat different approach to the problem of increasing the effectiveness of *M. helvolus* in interior areas was investigated during 1946 and 1947. This involved the direct infestation of the host plant, *Citrus,* with black scale crawlers. Inasmuch as the apparent reason for the lack of success of the parasite in controlling the black scale on citrus in the interior was the uniformly small size of the scale which made it unsuitable for parasitism during the summer months, it was reasoned that artificial infestation of the citrus trees with black scale crawlers somewhat earlier than the normal hatch occurred in the field might result in the presence of larger parasitizable scale on the trees during the summer. Accordingly, in co-operation with Howard Lorbeer, Manager of the Fillmore Citrus Protective District Insectary, Fillmore, California, artificial infestations of Valencia orange trees with thousands of black scale crawlers per tree were made in March and early April, 1946, near Piru, California, approximately 8 to 10 weeks before any appreciable amount of natural hatch occurred in the field. A comparison of scale developing from these artificial infestations with naturally developing scale is made in Table 1. The data in Table 1 show that active parasitization by *M. helvolus* may be maintained through the months of May, June and July, whereas under normal interior area conditions no active parasitization occurs during this period. Artificial infestation of the trees with black scale crawlers before the time they normally hatch in the late spring made this possible. Unfortunately, all of the artificially infested black scale had been completely eliminated by *M. helvolus* by early August, and practically no naturally occurring scale were yet of a size suitable for parasitization (optimum size 1·0 - 1·5 mm). As a result, *M. helvolus* still was virtually absent for a short period and complete practical success was not obtained.

In 1947 more intensive artificial infestation tests were carried out in the same grove as in 1946. These infestations were designed to cover at two-week intervals the period April 1 to June 1, inclusive, and to comprise single, double and triple infestations on individual trees at various dates. Dates for the first and last artificial infestations were delimited by the fact that April 8, 1946, colonizations carried production of *M. helvolus* only through July and that normal hatch is fairly general by June 1. In spite of the varying times and numbers

TABLE 1

Relative numbers, size and parasitization of artificially-infested versus natural hatch black scale. Piru, California, 1946.

Count Date	Scale from March 14 Artificial Infestation				Scale from April 8 Artificial Infestation				Natural Hatch Scale			
	Live Scale per leaf	Scale size-mm.		% parasitization	Live Scale per leaf	Scale size-mm.		% parasitization	Live Scale per leaf	Scale size-mm.		% parasitization
		Aver.	Range			Aver.	Range			Aver.	Range	
5/7	. .	0·37	0·26-0·52	trace	. .	0·31	0·22-0·39	none	none	(all old scale too large for parasitism		none
6/13*	3·5	0·77	0·39-1·29	28·2	4·6	0·60	0·30-0·95	19·3	. .	0·30	. .	none
7/9	1·1	1·08	0·65-2·24	47·6	1·2	0·95	0·65-1·46	14·3	7·9	0·60	0·43-0·77	none
8/9	all eliminated	. .	. .	. .	all eliminated	. .	. .	. .	4·2	0·71	0·47-1·12	trace
9/10	. .	. .	. .	. .	. .	. .	. .	. .	3·4	0·75	0·56-0·99	1·0

* Peak of natural hatch.

of artificial infestations, none on citrus succeeded in maintaining scale of a size suitable for parasitization by *M. helvolus* later than July. During July *M. helvolus* adults, both male and female, were commonly seen on trees bearing artificially infested scale. As in 1946, however, these colonized scale were completely eliminated by the parasites by August and the parasites failed to maintain themselves on the small natural-hatch scale.

Concurrent with the artificial infestations on citrus, artificial infestations were made on nightshade, *Solanum douglasii* Dugal. This was done as a result of 1946 field observations which indicated that natural hatch black scale grew more rapidly on nightshade than on citrus. Nightshade plants commonly grow under citrus trees as a perennial. In the past they have been considered essentially detrimental since they serve as a favourite host plant of black scale, so they are generally removed along with other weeds.

In planning the nightshade tests, it was thought that if black scale could be artificially infested at a date slightly earlier than the peak of normal-hatch (about June 1) and still attain the desired "helvolus size" during August, then a combination of early (about April 15) infestations on citrus and late (about May 20) infestations on nightshade growing together might succeed in maintaining *M. helvolus* field stocks through September. The comparative rate of growth of black scale crawlers artificially infested on nightshade, on various dates, and citrus growing together or on citrus alone is shown in Table 2. These data show that black scale does grow much more rapidly on nightshade than on citrus. These studies, unfortunately, were terminated by the accidental removal of most of the nightshade plants late in July by zealous, but uninformed orchard workers. Table 3 shows the per cent parasitization obtained on natural hatch scale in

TABLE 2

Comparative rate of growth of artificially infested and natural hatch black scale on citrus and on nightshade.
Piru, California, 1947.

	Size in mm. of Scale			
Count Date	4/1 Infestation on Citrus	5/1 Infestation on Citrus	5/1 Infestation on Nightshade	Natural Hatch on Citrus
5/15	0·66	0·46	0·59	None
6/3	0·81	0·68	0·89	0·51
7/1	1·08	0·79	0·98	0·64
8/1	..*	0·75*	0·89*	0·74
9/4		0·77*	1·11*	0·78

* All artificially infested scale was eliminated by 8/1/47. All scale on 8/1/47 and 9/4/47 counts were natural hatch scale.

TABLE 3

Per cent parasitization by *Metaphycus helvolus* of natural hatch black scale on citrus and on nightshade.

Piru, California, 1947.

Date	Citrus	Nightshade
8/1/47	0·09 – 1·8	11·1 – 40·6
9/4/47	trace	15·1

August and September on citrus trees and on nightshade from which the original artificial infestations had been eliminated by July. Obviously there was little or no carry-over of *helvolus* to "natural-hatch" scale on the citrus but there was an appreciable amount on the nightshade. All in all, our observations and data indicate that the combined infestation of nightshade growing together with citrus is much more promising than artificial infestations of citrus alone. Future tests, therefore, will involve the artificial infestation of well established large perennial nightshade plants under citrus trees.

It is felt that the satisfactory demonstration of the principles involved is highly encouraging, and that slight additional manipulation might result in complete success. No doubt there are many insect pests which have in their habitat enemies possessing the qualities necessary to bring about control were it not for the asynchronization of their populations with those of their enemies here considered. This fact is the basis for the belief that asynchronization may be overcome and biological control achieved, not only by mass-culture and periodic colonization of enemies, but also by culture and colonization of the pest insects themselves. Fundamentally this process differs little from vaccination, since it has as its objective the production of a mild, non-injurious infestation in order to prevent a heavy, injurious one.

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BIOLOGICAL CONTROL OF INSECTS IN NEW ZEALAND

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CULTURE OF ENTOMOPHAGOUS INSECTS

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INCOMPLETE natural control of pests that possess potentially effective natural enemies usually results because such enemies lack the capacity to be present in an active condition and in sufficient numbers to effect control at a time when the pest is susceptible to attack. Such enemies may be useful, however, if they can be cultured in large numbers and if the natural lack of synchronization between the two populations can be counteracted artificially by properly timed periodic liberations.

Liberations of entomophagous insects are generally motivated by three objectives: (1) the establishment of exotic introductions, (2) the hastening of population increase, and (3) the utilization of the released population to effect an immediate reduction of host densities. The first two objectives accomplish the reduction of the pest population through accretion of the population of natural enemies. The third objective maintains the pest population at a low density by inundating an area with a population of natural enemies (Flanders 1930b).

Success of the inundation method, with its system of periodic liberation is largely dependent on economy of production and liberation. Effective inundative liberations are economically made only when the host density is low and, usually, only when the number of individuals released during any given period exceeds the number of host individuals. The possibility of substituting, for the periodic applications of insecticides, entomophagous insects periodically released in inundative numbers, has been greatly enhanced by recent developments in the technique of culturing them. The purpose of this paper is to discuss the various types of culture methods and to describe the materials and procedure involved.

Types of Culture Methods Based on the Source and Kind of Host Material

Field-Collected Host Material.—In the biological control of some insect pests it is most economical to mass-culture their natural enemies on field-collected host material. This is particularly true in the introduction of foreign entomophagous species, since the host usually is abundant in the area to be colonized.

Field collection of the eggs of the gypsy moth, *Porthetria dispar* (L.), is practical and economical since the eggs are deposited in large masses, mainly on the trunks of trees, and persist from midsummer to the following spring (Crossman, 1925).

The habit of the range caterpillar, *Hemileuca oliviae* Ckll., of depositing its eggs in masses of several hundred in the form of cylinders around grass and weed stems also permit economical field collection (Frankenfeld and Barnes, 1933).

The European earwig, *Forficula auricularia* L., after attaining its third instar is readily collected in large numbers by means of artificial hiding places (Getzendaner, 1936).

Aphids such as the poplar gall aphid, *Pemphigus populi-transversus* Riley, can often be collected in quantities. Such material may be used in the mass culture of aphidophagous coccinellids, since it can be stored for months at freezing temperatures and high humidities (Haug, 1936).

The largest rearing programme undertaken with field-collected material has been with the spruce sawfly parasite *Microplectron fuscipennis* (Zett.), in Canada (Wilkes, 1947). Cocoons of the sawfly, *Gilpinia hercyniae* Htg., containing the larval and prepupal stages are collected from the forest floor and carefully cleaned and graded. Each cocoon is exposed to parasitization by one mated parasite female in a glass vial. All the progeny of this female may develop in a single cocoon. Using the vial method, with an inoculation ratio of one female parasite to one selected cocoon, twenty workers can handle a production of two million parasites per week at a total cost of 100 dollars per million. During the ten-year period 1935 to 1945, over 889 million parasites were released over the spruce-sawfly infested area. Labour costs can be greatly reduced by mass parasitization, however: an inoculation ratio of 5,000 *Microplectron* to 3,000 sawfly cocoons has been used successfully by Frank E. Miller (1940).

Laboratory-Reared Natural Host Material.—In the utilization of an established or indigenous entomophagous species, an inexpensive method of mass-culturing the host insect is essential, since an extraordinarily large number of the natural enemy is needed.

The first biological control project based on the mass culture of the host insect was developed in 1916, when the California State Department of Agriculture undertook the propagation of mealybugs (*Pseudococcus* spp.), on bleached potato sprouts, for use in the mass culture of the coccinellid *Cryptolaemus montrouzieri* Muls. (Smith and Armitage, 1931). In southern California the mass culture of *Cryptolaemus* has been continuous for about thirty years. In 1946 the combined production of seven *Cryptolaemus* insectaries was 40 million (Woglum, 1947).

The mass culture of the chalcidid *Leptomastix dactylopii* How. on the mealybug *Pseudococcus citri* (Risso) has been in progress at the Associates Insectary at Santa Paula since 1935. This parasite is released on citrus trees with incipient infestations of *P. citri.* The annual output at present is about 10 million parasites.

In an attempt to control the tick *Dermacenter andersoni* Stiles in Montana, ticks were reared on rabbits. While on the rabbits, the ticks were exposed to parasitization by *Hunterellus hookeri* How. for four to five hours. Parasites liberated in 1928 numbered approximately 381,000 (Morton, 1929).

The mass culture of the black scale, *Saissetia oleae* (Bern.), on green potato sprouts and on oleander, for use in the mass culture of the chalcidid *Metaphycus helvolus* (Comp.), has been in progress at the insectary of the Fillmore Citrus Protective District since 1937. The annual output at present is more than a million parasites.

The polyembryonic chalcidid *Copidosoma koehleri* Blanch., which was introduced into the United States from Chile in 1945 by the Commonwealth Bureau of Biological Control, was for a few months reared on the potato tuber moth at Riverside, California, at the rate of 10,000 per pound of egg-sized potatoes. Hundreds of thousands were released from a motor vehicle moving rapidly through host-inhabited areas.

Laboratory-Reared Factitious Host Material.—The natural host is not always amenable to propagation in quantity under laboratory conditions, so that the culture of its natural enemies may depend upon the use of a factitious host, that is, one that it does not attack under natural conditions.

In 1924 the egg parasite *Trichogramma* was reared experimentally on such factitious hosts as *Cimex lectularius* L. and *Ephestia kuehniella* Zell. (Hase, 1925). The Angoumois grain moth, *Sitotroga cerealella* (Oliv.), was the first factitious host utilized in mass cultures. *Sitotroga* was used in 1926 as a host of *Trichogramma*, which was propagated by the Saticoy Walnut Growers Association of Ventura County, California, for release against the codling moth on walnuts (Flanders, 1929, 1930a). This method was further developed by the

United States Department of Agriculture so that it is now possible to produce a million *Trichogramma* a day, at a cost of 6·50 dollars per million (Spencer, Brown and Phillips, 1935).

The potato tuber moth, *Gnorimoschema operculella* (Zell.), has been propagated in large numbers by the University of California for use in the mass culture of the oriental fruit moth parasite *Macrocentrus ancylivorus* Roh. (Flanders, 1943c). During the 1947 season, more than 28 million *Macrocentrus* were produced, a production greatly in excess of that possible with its natural host, *Ancylis comptana fragariae* (W. & R.). The potato tuber moth also serves as a laboratory host for the corn-borer parasite *Cremastus flavoorbitalis* (Cam.). The potato tuber moth egg yields larger *Trichogramma* than does the egg of *Sitotroga* (Flanders, 1945c).

According to Simmonds (1944), there are two types of factitious hosts: type 1, on which the parasites will deposit eggs; and type 2, on which the parasites will not oviposit, but which is suitable for the normal development of the parasite. The Mediterranean flour moth, *Ephestia kuehniella*, has been successfully used as a type-1 host for three species of *Chelonus* and several species of *Microbracon* (Bradley, 1941). *Ephestia kuehniella* is also a type-2 host suitable for the mass culture of the codling moth parasites *Cryptus sexannulatus* Grav., *Ephialtes caucatus* Ratz., and *Aenoplex carpocapsae* Cush. The utilization of a type-2 host necessitates the use of a cocooned natural host as a "trap" host in order to obtain the eggs of the parasites for transfer to the factitious host. The transfer of parasite eggs from "trap hosts" was used in the mass culture of the corn-borer parasite *Exeristes roborator* (Fab.) (Baker & Jones, 1934).

Culture Requirements and Limiting Factors

The mass culture of any insect is contingent upon its amenability or preadaptation to artificial conditions, and upon the availability of its food. The first step in ascertaining the limitations of a project is a biological study of the species concerned, a study to determine the habitudinal characteristics that preadapt them to an artificial environment. Some species (*Perisierola emigrata* Roh., for example) are amenable to individual culturing but not to culturing *en masse.*

The facility with which preadapted species are cultured is determined in part by the accessibility and mobility of the host stages attacked. The external parasites of relatively large hosts kill or paralyze them before oviposition. Univoltine parasites of single-brooded hosts, that is, of hosts that undergo diapause, are difficult to mass-culture economically because of the low rate of turnover and the amount of space and time involved in production.

In general, the problem involved in the mass culture of a preadapted entomophagous insect include (1) obtaining a host-supporting medium that is abundant and cheap, (2) finding a readily reared host, (3) providing conditions which will yield the maximum number of entomophagous females per unit of cost, and (4) synchronizing production with the requirements for field liberation.

Kinds of Host-Supporting Media

The development of artificial media for the propagation of the host insects may be the next advance in the mass culture of entomophagous insects. In Africa a medium consisting of oatmeal porridge lightly infected with the mold *Mucor hiemalis* Wehmer has been used successfully in propagating the false codling moth, *Argyroploce leucotreta* Meyr. (Ripley, Hepburn & Dick, 1939). The onion and cabbage maggots *Hylemya antiqua* (Meig.) and *H. brassicae* (Bouché) have been successfully reared on an agar medium with an infusion of onion and cabbage (Eyre, 1921).

As stated by Simmonds (1944): " . . . the propagation of parasites on unnatural hosts and the possibilities of the use of artificial media are of great practical importance in the breeding of parasites in biological control work." He points out that the parasites bred in such a way are still capable of attacking their natural hosts in the field, and that such breeding is extremely unlikely to interfere with the establishment of an introduced species.

The ideal host-supporting medium is one that is (1) nutritionally complete, (2) always available for use, (3) readily handled, and (4) slow to deteriorate.

Host-supporting media that have been found useful for certain insects and mites are listed below:

- Dry plant tissues (grains, seeds, fruits) for stored-products insects, and corn meal for *Pyroderces rileyi* (Walsm.).
- Sugar beet roots for soft scales.
- Sago palm for long-tailed mealybug and black scale.
- Oleander and potato sprouts (green) for black scale.
- Squash, citron melon, and potato tubers for diaspine scales.
- Citron melon for soft brown scale and long-tailed mealybug (Flanders, 1944a).
- Potato tubers for cutworms and tuber moth.
- Potato sprouts (bleached) for mealybugs.

The dry seeds of certain plants are well suited to host propagation. This type of medium supports a relatively large number of insect species. The size and moisture content of the seeds may affect their usefulness, however. In the propagation of *Sitotroga cerealella* (Oliv.), the total production per unit weight of grain is reached much more rapidly with wheat than with corn, apparently because of the internecine action of the larvae. Since a kernel of grain, irrespective of its size, is usually inhabited by only one *Sitotroga* larva at a time, the smaller the kernel the more rapidly it is utilized and consumed. The advantages derived from a rapid turnover of material more than offset the additional labour involved (Flanders, 1934).

The sugar beet holds promise as a suitable medium for leaf-feeding insects and mites. The oleander has been used for a number of years by the Fillmore Citrus Protective District as a medium for propagating the black scale. The citron melon has been used for the propagation of the soft brown scale, *Coccus hesperidum* L. In actual practice, however, the potato holds the lead as a medium for propagating insects to serve as laboratory hosts. Varietal differences in potatoes affect their usefulness; Bliss Triumph produces the best sprouts for culturing mealybugs and black scale, White Rose is most suitable for culturing red scale, and Idaho Russet for tuber moth.

The potato was first used in Russia when Pospielov (1913) used sliced potatoes in the propagation of the cutworm, *Euxoa* sp., in order to obtain eggs for the culture of *Trichogramma* for use against the apple codling moth. In 1916 Smith (Branigan, 1916) developed a method for propagating various species of mealybugs (*Pseudococcus* spp.) on potato sprouts lacking chlorophyll (grown in the dark), and for propagating the black scale, *Saissetia oleae,* on potato sprouts possessing chlorophyll (grown in the light). Mealybugs infesting potato sprouts have been used for the mass culture of *Cryptolaemus montrouzieri, Leptomastix dactylopii, Coccophagus gurneyi* Compere, *Tetracnemus pretiosus* Timb., and many other natural enemies. Black scale on potato sprouts has been used for the mass culture of *Metaphycus helvolus, M. stanleyi* Compere, *Coccophagus heteropneusticus* Compere, and others (Flanders, 1942). Aphids on potato sprouts have been used at intervals in the Riverside insectary of the University of California Division of Biological Control for the propagation of *Lysiphlebus.*

In 1943 the potato tuber moth, *Gnorimoschema operculella,* which is a pest in insectaries propagating mealybugs, was found to be a suitable host for the mass culture of *Macrocentrus ancylivorus.* The egg-sized potato tuber became the base food in the culture of *Macrocentrus,* more than 200,000 pounds being used for this purpose in 1947 in insectaries in eastern and western United States.

In the fall of 1946 the smooth-skinned potato tuber came into use as a host-supporting medium for diaspine scale insects such as *Hemiberlesia lataniae* (Sign.) and the red scale, *Aonidiella aurantii* (Mask.) (Flanders, 1947). The potato tuber proved to be more suitable for the mass propagation of red scale than plants previously used, such as date palm seedlings, iris plants, sago palm, and the fruits of citrus, citrullus, and cucurbita.

The potato is an excellent example of a host-supporting medium for the following reasons:

(1) It eliminates the necessity for providing facilities for host-plant propagation, since an adequate supply of the tuber can be purchased cheaply in the open market throughout most of the year.

(2) It can be held in cold storage for a year or more if necessary.

(3) It can be housed so that it provides the maximum scale-supporting area per unit of space.

(4) Without loss of viability, it can support, for five months, a scale infestation covering its entire surface. Since the mature red scale produces young over a period of a month or more, its efficient use requires that it inhabit a host plant which remains viable during this period at least.

(5) It is more suitable than other media for artificial infestation with scale, as well as for self-infestation, and can be infested readily without wastage. The variety of potato affects the amount of infestation and of parasitization (Flanders, 1945b), a flat type of potato, such as White Rose, being especially suitable.

(6) Loss of scale due to deterioration of food plant is less with the potato than with melons or squash.

(7) Host-infested potato tubers, being readily handled in compact units, are most efficiently exposed to parasitization.

(8) It permits utilization of self-perpetuating host-parasite populations housed so that the processes of infesting, parasitizing, and collecting of parasites are automatic.

(9) It can be completely infested with scales of equal age, permitting a maximum production of natural enemies in the minimum of time and space.

(10) Potatoes being in small units facilitate the liberation of immature entomophagous insects.

Qualifications of the Laboratory Insect Host

The ideal laboratory insect host is (1) a general feeder, (2) has a rapid rate of increase (a short life cycle and high fecundity per female), (3) exhibits little if any internecine action, (4) is highly immune to disease, (5) produces no by-products (sticky secretions, webbing, wax) to interfere with the attack of the entomophagous species, and (6) is readily accepted by the species which is to be mass-cultured.

The coccid *Hemiberlesia lataniae* has most of the qualities of the ideal host and is a perfect laboratory host for predators of red scale. It reproduces without males, and the females are robust and highly fecund. It is, however, highly susceptible to attack by the mite *Hemisarcoptes malus* Shimer.

The newly hatched scale "crawlers" of many coccids such as *Saissetia oleae, Coccus hesperidum,* and *Icerya purchasi* Mask. are positively phototropic and therefore may be readily collected in quantities by placing the parental material in a box so constructed that light enters horizontally from one direction. The crawlers then migrate toward the light. If the light enters through a V-shaped opening an inch or so above the floor of the box, the crawlers converge to a point where they are blocked by a shadow, and are forced to pile up. In the propagation of mealybugs, the young are transfererd from old, infested potato sprouts to fresh potato sprouts by means of temporary hosts such as leaves of the pepper tree (*Schinus molle*) or of mustard. Leaves of this type are attractive to the mealybug when fresh, but they dry out quickly and thus become unattractive and cause the mealybugs to move on to the sprouts.

The potato tuber moth, *Gnorimoschema operculella,* is an excellent laboratory host despite the fact that it is subject to various diseases. If the material is handled properly, these diseases do little damage. The fact that this species normally constructs its cocoon in sand, a chemically inert material, facilitates the separation of the host and its parasites, since the sand does not react with the sodium hypochlorite that is used in dissolving the cocooning silk. The fact that oviposition is stimulated by a certain type of surface facilitates the collection of eggs.

The Angoumois grain moth, *Sitotroga cerealella* (Oliv.), also is an excellent laboratory host. The feeding and pupal stages occur within the kernels of grain, which can be handled in bulk and do not become matted with webbing and excreta, as is the case with *Ephestia* spp. The adults are negatively geotropic, negatively phototropic, and positively thigmotropic to such an extent that they are readily collected.

The internecine activity of host larvae usually is a detrimental factor. With *Sitotroga* this difficulty is obviated by the use of small grains. With *Ephestia kuehniella* and *Popillia japonica* Newm., the habit is expensive in labour and equipment. In the culture of such species, conditions conducive to proper mating must be provided.

Control of Insectary Pest Organisms

Since the host-supporting media and the host serve as food material for various organisms other than those being purposefully reared, such organisms may become established in the culture as serious pests. It is most essential that the stock or mother population be kept free of pest organisms, that is, of organisms that interfere with or prevent the efficient production of the host organism.

Measures necessary to prevent contamination of the cultures are: (1) rapid turnover and destruction of used material, (2) the use of small breeding units to facilitate the detection of pests and their elimination, (3) destruction of possible sources of pests in neighbourhood of laboratory, and (4) routine sterilization of all equipment and material.

Natural enemies of the pests may sometimes be used to control them. The predatory thrips, *Scolothrips sexmaculatus* Perg., has been used to control the red spider (Pacific mite), *Tetranychus pacificus* McG., which interferes with the culture of *Comperiella bifasciata* How. (Flanders, 1943a). The chalcid *Acerophagus pallidus* Timb., has been used to control the potato mealybug, *Phenacoccus solani* Ferris, which interferes with the propagation of black scale. Since this parasite does not attack mealybugs that are underground, it is incompletely effective (Flanders, 1944b). The bethylid *Cephalonomia waterstoni* Gahan completely eradicated an infestation of the beetle *Laemophloeus pusillus* (Schön.), the larvae of which were exceptionally destructive to the eggs of *Sitotroga* (Schread & Garman, 1933).

Insecticides are used to prevent rather than to control pest infestations in culture operations.

In the propagation of *Sitotroga* the host-supporting medium (wheat) is dipped in hot water to kill possible pests, as well as to increase the moisture content of the grain. The eggs of *Sitotroga* are immersed momentarily in carbon disulphide to prevent mite infestation (Spencer, Brown & Phillips, 1935). In the mass propagation of the false codling moth, the eggs, with embryo well developed, are treated with commercial formalin, one part formalin to five parts of water. In the mass propagation of the potato tuber moth, the eggs are immersed in hot water to prevent the development of microsporidia.

The organism most generally feared by insectary operators is the straw itch mite, *Pediculoides ventricosus* Newp. This mite is a temporary parasite of man, causing an irritating skin rash. It will completely destroy a culture of insects in a remarkably short time. Outbreaks of this mite are readily prevented by a rapid turnover of material and by sanitation.

Other organisms that have been detrimental in the mass cultures are listed below under their respective hosts:

Angoumois grain moth: *Dibrachys cavus* Wek., *Habrocytus cerealellae* Ashm., *Sitophilus oryza* (L.), *Tribolium confusum* Duv., *Tyroglyphus* sp.

Mealybugs: *Aphis* spp., *Leptomastidea abnormis* (Gir.), *Sympherobius* spp.

Latania scale: *Gnorimoschema operculella* (Zell.), *Hemisarcoptes malus* (Shimer), *Lindorus lophanthae* (Blaisdell), mealybugs.

Pests that develop only on certain host stages may be eliminated by isolating the host material equal in age so that the interval between suitable stages is sufficient to starve out the pest. This may require a period of several host generations. The mite *Hemisarcoptes malus* attacks latania scales after the newly hatched crawlers force their way out from beneath the scale covering. The best insurance against damage by such a pest is to have uniformly developed host infestations, so that there may be a long period in which there are no hosts suitable for the development of the pest. With latania scale, the mature infestations should be utilized before two generations of the mite can develop. Red scale is largely immune to attacks by this mite because the body of the female scale closely adheres to the scale covering.

REPRODUCTION OF THE ENTOMOPHAGOUS INSECT

Mating.—The principal obstacle to the mass culture of many entomophagous species is mating, particularly in those species which usually mate in flight. In such cases special provisions for mating are necessary, and these provisions may vary as greatly between species as between families or even orders. The Chalcidoidea, however, usually mate readily without special provision (Flanders, 1943b).

The females of the Tachinidae usually mate only once. Repeated matings have been noted in several species. Mating may be induced in the Tachinidae (1) by shaking the container so as to cause the adults to tumble together; (2) by placing large numbers of the adults (males predominating) in large screen cages, outdoors, shaded from the sun; and (3) by transferring screen containers from shade to bright sunlight.

The range of light intensity favourable to mating may be narrow. Species that are diurnal in habit usually mate most freely during morning hours, with increasing light and temperatures, whereas species that are crepuscular or nocturnal in habit mate as light and temperature decline. Mating and attempted oviposition are not to be taken as conclusive evidence that the females are impregnated. In the Tachinidae, the absence of eggs in the posterior uterus generally may be taken as evidence of lack of mating.

The females of the Tachinidae and Hymenoptera usually are sexually mature immediately after emergence, whereas the males show little tendency to mate until one or several days after emergence. The developmental period of the immature stages of the male is less than that of the female, however, by one or several days, so that the males are usually present and sexually mature when the females emerge. In the Hymenoptera, newly emerged females, particularly those of gregarious species, mate most readily. Mating should occur during the preoviposition period to ensure maximum production. The female often loses the mating instinct; the male rarely if ever does so.

The majority of species mate most readily at temperatures of 65° to 75° F., which are below the optimum maximum for oviposition and development. Mating in containers may be inhibited if the air becomes so saturated with the odour of the females that it is not a distinguishing factor, there being no gradient by which the male is directed to the female. If the females refuse to mate under any circumstances, as with *Habrolepis rouxi* Compere, mating may be unnecessary for reproduction.

Flight may be a prelude to mating in certain species. The Opiinae, particularly, are difficult to mate in indoor cages. Use of large outdoor cages, if shaded, may be satisfactory.

Macrocentrus females under normal conditions mate but once. Conditions that enable females to mate several times cause them to produce more male than female progeny (Flanders, 1945a).

Females that are unmated because of aging or other unfavourable conditions may be induced to mate (1) by brushing their bodies with larval skins of newly emerged females, (2) by withholding nourishment for several hours and then presenting them with food in the presence of full-fed males, (3) by exposure to air movement produced by an electric fan, (4) by a sudden increase in temperature to the optimum in the presence of bright light, (5) by subjecting them to anaesthetization or by chilling and subsequently confining them with males immediately after recovery but before regaining full activity, or (6) merely by having a certain ratio of males to females.[1]

Inbreeding.—The reproductive qualities of an entomophagous insect under mass culture are not adversely affected by continuous propagation, generation after generation, under the same conditions.

Degeneration of breeding stock has been reported from time to time, but an investigation has in each case shown it to be an effect of improper handling. A decline in proportion of females in successive generations, to the point of extinction, such as has occurred in the cultures of certain braconids and ichneumonids, is remedied by handling the material so that the female upon receiving the spermatophore from the male is able to adjust it and become impregnated.

Inbreeding has no effect on the fecundity of the female. In many species, under natural conditions, inbreeding is the rule, particularly in gregarious species such as those of *Melittobia* and *Telenomus*, which mate before emerging from their hosts. In fact, observations by Schmieder & Whiting (1947) indicate that with *Melittobia* inbreeding increases fecundity.

Selective breeding for fecundity under culture conditions appears to be of little if any value, since in most cases the food supply is fully utilized. Simmonds (1947) and Wilkes (1947) report that selective mating can be used to increase the proportion of females in cultures in which the sex ratios have been declining. Selective breeding in the insectary, however, may establish characteristics that would be unfavourable to survival in the field.

The efficiency of culture operations is measured by the number of entomophagous females reared per unit of space. This depends, in part, upon the sex ratio. With species of Coccinellidae and Tachinidae, the sex ratio of deposited eggs, in proportion to females, is 0·5. With biparental Hymenoptera, however, the sex ratio of deposited eggs is extremely variable. Under conditions of cannibalism or of superparasitism a differential mortality of the sexes may affect the sex ratio.

Regulation of the Sex Ratio.—In the culture of biparental parasitic Hymenoptera, the stage of host development and host density may determine the sex ratio, provided the parental females have been successfully mated. Females of such species as *Typhia popilliavora* Roh.

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[1] Clausen, C. P. Unpublished notes.

and *Metaphycus helvolus* tend to deposit male-producing eggs on small hosts and female-producing eggs on large hosts. Females of *Coccophagus ochraceus* How. tend to produce more male progeny than female when host density is high. The normal sex ratio of gregarious species like *Microplectron* is more likely to be modified by the condition of the individual host than by host density.

Male Hyperparasitism.—With many hymenopterous species of the aphelinid group, the male develops only as a hyperparasite of the female. Consequently, in such species there is a tendency for female populations to alternate with male populations. Particular attention should be given to the mating of such species so that the liberations may consist of mated females.

Nutrition.—With some entomophagous species, propagation under artificial conditions requires special attention to nutrition. Oviposition by the adult green lacewing, for example, can be regulated by the supply of honeydew produced by mealybugs. After a preoviposition period of two weeks, normal oviposition can be induced only by feeding on honeydew. Thereafter, when honeydew is withheld, oviposition immediately begins to decrease to a mere trace, although the female may be feeding heavily on bee's honey (Finney, 1948). Maximum oviposition by many parasitic Hymenoptera and Diptera requires daily feeding on carbohydrates such as bee's honey. When honey is used for food, the relative humidity should range between 50 and 60 per cent.

Effects of Humidity.—Humidity requirements vary with the kind of insects cultured. Latania scale requires a higher humidity than red scale. The newly hatched larvae of predators such as coccinellids and lacewings are readily desiccated at low humidities. The younger stages of Hymenoptera are usually protected, so that high humidities are less injurious in the cultures of Hymenoptera than in those of coccinellids. With species like *Macrocentrus*, oviposition does not occur at low humidities (Martin, 1946a). The olfactory recognition of the host by the parasite may depend on the amount of water vapour in the air (Flanders, 1944c). High humidity favours the development of the sugar mite, which is highly destructive to the quiescent stages of coccinellids. A relative humidity of 50 to 60 per cent is needed to maintain carbohydrate food in edible condition.

Mutilation of Host.—Parasitic Hymenoptera often use the ovipositor as an instrument for mutilating the viscera of the host. This is usually done in preparation for feeding on the contents of the host. This habit, however, may become pernicious and completely prevent reproduction when the parasites are presented with hosts before such hosts are large enough for the development of the offspring of the parasite. *Aphytis* sp., an ectoparasite of red scale, has thus completely destroyed a host population, no reproduction of either host or parasite occurring.

CULTURE PROCEDURES

Segregation of Operations.—Three distinct operations are involved in mass culture of entomophagous insects, namely, (1) the preparation of the host-supporting medium, (2) the propagation of the host, and (3) the culture of the entomophagous species. Under artificial conditions, as under natural conditions, these operations may be more or less segregated: in the field or in very large cages, by time and space; in the laboratory, by insect-proof partitions. In the field, segregation is automatic and prevents both host and entomophagous species from committing race-suicide. Under insectary conditions, segregation permits mass culture at maximum densities.

Since in mass culture 100 per cent parasitization of the host rarely occurs, it may be necessary to separate the mixed populations if the hosts that escape parasitization are to be used for infesting fresh host-supporting media, or if the host-feeding species is to be released in areas where the laboratory host is also a field pest.

In the mass culture of the oriental fruit moth parasite *Macrocentrus ancylivorus*, separate stock cultures of the laboratory host are unnecessary if it is propagated on the Russet variety of potato, since a relatively higher proportion of the host escapes parasitization with this variety than with the White Rose.

Periods of Operation.—For economy of operation, the developmental periods of host and entomophagous insects are shortened to the minimum in the following ways: (1) by holding the material constantly at the maximum temperatures and humidities for normal development —usually 82° F., and at 50 per cent relative humidity; (2) by utilizing hosts equal in development; and (3) by obtaining maximum use of the hosts through eliminating the need for searching by the host-feeding species.

A rapid turnover of material minimizes the amount of space and equipment needed to produce a given number of entomophagous insects; the number of individuals produced per unit of space is a criterion of efficiency of operation. The continuity of operations which is essential for the efficient use of labour and material necessitates, with entomophagous species such as *Macrocentrus,* the segregation of operations. With species such as *Aphytis,* this combination of operations in self-perpetuating units provides maximum economy of space and labour. However, even with this species, maximum economy in food and food base is obtained when the operations are segregated.

Handling of the Populations.—In the parasite or predator breeding rooms, as in the host breeding rooms, the ratio of inoculum (the initial number of individuals) to the amount of food available must be such as to obtain the maximum production in a minimum of time. This ratio varies greatly with the species concerned.

(a) *Introduction of Prey Populations into a Predator Population.*— With predator populations in which the individual consumes many hosts in order to complete development, efficient propagation may require the introduction of hosts into the predator populations, as in the propagation of *Chrysopa* sp., in which the eggs and larvae of the potato tuber moth are fed at intervals to the larval stages of *Chrysopa.* Likewise, in the culture of coccinellids, the host material is introduced.

The nature of attack may make it necessary either to remove part of the predator population in order to prevent starvation, or to add predators, as in *Chrysopa* production, in sufficient numbers to efficiently consume the host. Uniformity in production, a necessary condition for economical production, may require a high ratio of adult predator to host, in which case the period of exposure must be limited.

(b) *Introduction of Predator Populations into a Prey Population.*— In the mass culture of *Cryptolaemus montrouzieri*, an inoculum of 20 adults yields progeny numbering about 2,000. The host population must be sufficient to enable all the progeny to reach maturity.

(c) *Introduction of Host Populations into Parasite Populations.*—In the culture of parasites such as *Aphytis* sp., which attack a host species throughout a wide range of its developmental stages but can develop successfully only within a very limited range of such stages, the efficient use of the host (and consequently its food base) necessitates its being exposed to attack only when in the stages of the limited range, such stages being most suitable for the complete development of the parasite in a minimum amount of time. This can be done only by segregation of operation, and for this additional space is required for completely infesting the food base with hosts of equal age, and for storing them until they are in a stage most suitable for parasite production. This procedure also requires additional labour both for infesting and for collection. The decision as to which method to use is a matter of economics.

Comperiella bifasciata attacks all stages of the red scale except eggs, active crawlers, and adult males. It develops most successfully, however, when it attacks the early stages of the third-instar scale. When the attack occurs in the first instar, a high proportion of both scale and parasite die without further development. When the attack occurs in the late third instar, a high population of the developing parasites may die from lack of sufficient nourishment. Consequently, the most efficient use of the scale is obtained when it is introduced into the parasite population during the early third instar. This can be done if the food base is infested uniformly with red scale of equal age.

Aphytis sp. attacks the settled red scale throughout its first and second instar and early part of the third instar, or until shortly after mating. Development under mass culture is successful only in the early part of the second and third instars of the female and the prepupal stage of the male scale. Attacks during the earlier stages merely result in death of the scale without production of parasites. Since the size of the host influences the size and number of parasites developing upon it, the efficient use of scale and food base necessitates exposure of the scale to parasitism only when it is in the early third instar.

The parasite population should be sufficient to parasitize most of the scale during a short period of exposure. The parasitized scale is then removed and placed in closed trays for the automatic collection of the parasite adults. The habit of most parasites of concentrating in lighted areas permits efficient production in properly constructed breeding rooms. The parasite population can be drawn from areas containing parasitized hosts to areas containing unparasitized hosts by manipulation of the lighting.

(d) *Introduction of Hosts Individually into a Parasite Population.*—In the culture of parasites it is sometimes more efficient to introduce the host individuals into a parasite population, in which case the hosts are removed as soon as attacked. Such a method is utilized in propagating species like the tachinids *Sturmia* sp. and *Bigonicheta setipennis*, and the bethylid *Perisierola emigrata* (Coppel & House, 1947). This method, however, like the "vial" method, in which the entomophagous insect is handled individually, is laborious.

(e) *Introduction of a Parasite Population into a Host Population.*—When the inoculum is parasitic, it may not be economical to remove it for further utilization. Many parasites under mass culture are discarded before they deposit their full quota of eggs. The females of *Macrocentrus*, for example, are never utilized to their full capacity. In cultures of *Macrocentrus* on oriental fruit moth, Van Steenburgh & Boyce (1937) increased the number of hosts parasitized, and consequently the total parasite production, by adding to the inoculum an intrinsically inferior parasite, *Ascogaster carpocapsae* Vier.

High fecundity of the female parasite is not a prerequisite for efficient culture, however. Uniformity in development of the host population under laboratory conditions limits the period of attack of parasites and makes necessary a larger inoculum. An increase in the development rate of the parasite by using temperatures that lower the fecundity of the species may increase production. In *Trichogramma* production, for example, the shortening of the life cycle at temperatures of about 86° F. more than offsets the higher productivity *per female* at 77° F. (Lund, 1938).

(f) *Contact of a Parasite Population with Host Populations Through Thin-Walled Partition.*—This method is most efficient in utilizing both host and parasite populations with a minimum amount of handling. It was first used on a large scale by Doutt & Finney (1947) in culturing *Dibrachys cavus* (Walker) on potato tuber moth larvae. Since this type of culture method may be applicable to many species, Doutt and Finney's description of it is quoted below:

"The stock of parasites is maintained in shallow wooden boxes fitted with tight cloth covers . . . The adult *Dibrachys* are put into each container through the 1-inch hole in the end and additional parasites are added daily in order to maintain the population of active females. These *Dibrachys* containers serve as parasitization units.

"Mature larvae of *Gnorimoschema operculella* are used as hosts for *Dibrachys*. These larvae are collected in quantity by first permitting them to cocoon in sand on the cocooning plates placed within the electric barrier (Finney *et al.*, 1947) and then freeing them from their cocoons by processing with sodium hypochlorite solution as described by Bartlett & Martin (1945) and also by Martin & Finney (1946). The larvae thus collected are immediately immersed in a hot water bath (135° F.) for two minutes. This water bath also contains paraffin wax with a low melting point (43° C. to 47° C.) and a blood albumin spreader. A somewhat similar method was used by Theron (1945) to condition larvae of the codling moth for attack by ectoparasitic ichneumonids. When the larvae are removed from the water bath they are spread on wooden-framed, cloth trays about 40 by 20 inches. These trays are placed upon the cloth covers of the parasitization units and are then dampened. Upon drying, the cloth of the units and the cloth of the trays seal together. The *Dibrachys* females oviposit readily through the two layers of cloth, which deter them no more than the silken wall of any host cocoon. The host larvae, although killed by the hot water treatment and coated with paraffin wax, remain attractive to the parasites.

"The cloth trays containing the parasitized host larvae are removed from the parasitization units daily. These are held for 14 days at a constant temperature of 82° F. At the end of 14 days the *Dibrachys* have consumed their hosts and have developed to the mature pupal stage. The *Dibrachys* pupae are separated from the remaining host material by sifting through a 16 mesh wire screen."

Entomophagous species may be handled individually, as with *Microplectron fuscipennis* or *Typhia popilliavora*, or collectively, as with *Trichogramma* or *Macrocentrus*. Individual handling increases labour costs per insect reared, although a much greater number of progeny are reared per parent. The ratio of increase, for example, is much greater in the mass culture of *Chelonus* or *Microplectron* than with *Trichogramma* or *Cryptolaemus*.

COMBINATION OF OPERATIONS, IN THAT HOST-PARASITE POPULATIONS ARE SELF-PERPETUATING

With certain entomophagous species, it is feasible to combine the operations of host propagation and of culture of the entomophagous species. These operations take place within a unit which is set up more or less permanently. In such a unit infestation and parasitization are automatic. With entomophagous insects possessing strong tropism the use of proper equipment will make their collection automatic also.

A self-perpetuating automatic-collecting population has been established using the potato tuber, red scale, and its endoparasite, *Aspidiotiphagus* sp. All the material is housed in a shallow box, one end consisting of a transparent, open-ended cone exposed to light, and the other end opened but dark. The floor of the box is covered with a layer of potatoes infested with parasitized scale. A layer of uninfested potatoes is then placed upon the infested layer. Thereafter, at intervals of several months, the old potatoes are removed and replaced with fresh ones. The newly emerged parasites being positively phototropic move to the end of the cone and are trapped in a vial placed over the apex. The vials containing the parasites are removed daily. Enough parasites oviposit before being trapped in the vial to maintain the culture.

The invasion of a self-perpetuating unit by a pest organism soon destroys the culture.

THE DEVELOPMENT OF A MASS-CULTURE PROJECT (MACROCENTRUS ANCYLIVORUS)

The development of the mass culture of *Macrocentrus ancylivorus* by the Division of Biological Control of the University of California during the period 1943 to 1947, inclusive, provides an interesting example of the problems involved in such a project (Finney, Flanders & Smith, 1947).

Experimental work began in March, 1943, four months after the discovery that the oriental fruit moth, *Grapholitha molesta* (Busck), occurred in California. The use of the field-cage method of *Macrocentrus* production developed in the eastern United States was considered impractical from the standpoint of producing *Macrocentrus* in numbers sufficient to cover the peach-growing areas of California in the event that they should become seriously infested. Also, the strawberry leaf-roller, *Ancylis comptana fragariae* (W. & R.), which serves as a host of *Macrocentrus* in the east, does not occur in southern California.

The first problem was to find, if possible, an insect in which *Macrocentrus* would oviposit and develop, and which could be readily propagated in containers easily handled. Two species were available in numbers for immediate testing—the Mediterranean flour moth, *Ephestia kuehniella,* and the potato tuber moth, *Gnorimoschema operculella.* Only the tuber moth proved attractive to *Macrocentrus* and suitable for its development.

Of the parts of the potato plant habitable by the moth *Gnorimoschema operculella,* the tuber can be handled most efficiently, since it furnishes the most food in the least space. The newly hatched tuber moth larvae normally enter the potato at the "eyes", but under mass infestation the concentration of larvae at the "eyes" results in excessive competition, which slows up development, delays the consumption of the potato, and reduces turnover. In order to obtain maximum production in a minimum of time and space, it was necessary to add artificial "eyes"; this was done by puncturing the potatoes by rolling them between brad-studded flexible leather pads.

To facilitate the operations of infestation by the tuber moth, of exposing tuber moth to attack by *Macrocentrus,* and of collecting the cocoons of full-fed, parasitized and unparasitized hosts, the punctured potatoes were placed one-layer deep on trays that were made of hardware cloth and were as large as could be handled easily.

The problem of obtaining uniform infesting material (in this case tuber moth eggs) in sufficiently large amounts was solved by the discovery that the female host preferred to oviposit on rough ventral surfaces, particularly when such surfaces consisted of a type of cloth having a fibrous nap. The ovipositing moths were placed for oviposition in a very shallow wooden box having smooth sides and floor and a removable cloth top. A method of anaesthetizing the moth adults with a nonexplosive mixture of ether and carbon dioxide was developed so that the moths could be placed in the oviposition cage in measured amounts, the dead moths removed, and the egg cloth removed and replaced without any moths escaping. The size of the egg deposition boxes was made to correspond with the potato-covered area of the hardware-cloth trays, so that the cloth bearing the moth eggs would cover the potatoes completely and permit the transfer of the newly hatched host larvae to the newly punctured potatoes.

The problem of obtaining the maximum possible parasitization of host larvae by *Macrocentrus* was solved by placing the trayed potatoes in a shallow box so constructed that the parasite inoculum would be confined to a limited space around the infested potatoes and the moisture given off by the potatoes would create the atmospheric humidity essential for oviposition by *Macrocentrus.* Prior to the introduction of the parasites into the parasitization box, the egg sheet had to be removed.

The full-fed tuber moth larvae, parasitized as well as unparasitized, have the habit of migrating to the ground and spinning their cocoons on dirt and debris. The problem of economically separating host and parasite was solved by removing the trays of infested potatoes from the parasitization boxes and stacking them over beds of plaster sand placed on waxed boards. The cocoons, which were embedded in the sand, were removed daily so that the larvae would be equal in development, and they were held until the unparasitized larvae had pupated. Then the cocoons were immersed in a sodium hypochlorite solution to dissolve the silk and release the host pupae and the parasite parchment cocoons. This material was strained out, rinsed in water, and then separated by immersion in dilute alcohol, in which the host pupae settled and the parasite cocoons floated. The separation of host and parasite prior to their emergence greatly simplified handling for production, shipment, and release in the field.

The problem of confining the migrating tuber moth larvae to the cocooning beds of sand was solved by the development of the hot wire barrier.

The problem of obtaining the most favourable sex ratio was solved by the discovery that excess mating prevented the complete impregnation of the female. Excess mating was prevented by having the mating chamber unlighted.

SUMMARY

Methods for culturing entomophagous insects are of several types based on the source and kind of host material, as field-collected or laboratory-reared, natural or factitious.

Cultural requirements are discussed with respect to limiting factors, kinds of host-supporting media, qualifications of laboratory host, control of insectary pest organisms, and factors bearing on the reproduction of the entomophagous insect under artificial conditions.

Culture operations include (1) the preparation of the host-supporting medium, (2) the propagation of the host, and (3) the culture of the entomophagous species. The second and third operations may be employed either separately or in combination. When the operations are separate, the procedure is either to introduce the host as individuals or as a population into the parasite/predator populations, or to introduce the parasite into the host population, or to bring the host and parasite in contact through a thin-walled partition. When operations are combined, the processes of infestation (propagation of host) and parasitization (culture of parasite) are automatic and contained in a single operating unit.

With certain entomophagous species, collection of the reared material can also be done automatically by utilizing their tropic responses.

The development of a culture project is exemplified by a detailed account of that of *Macrocentrus ancylivorus* Roh.

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SOME NATURAL ENEMIES OF SNAILS OF THE GENUS *ACHATINA* IN EAST AFRICA

By Francis X. Williams, California.

[*Abstract*]

The African land snail *Achatina fulica* Bowdich has been introduced into many parts of the Pacific, where it has become destructive to certain agricultural crops and other vegetation. To safeguard the food crops of the inhabitants of Micronesia the writer investigated natural enemies of this and related snails in tropical East Africa during the first half of 1948. This project was under the direction of the Insect Control Committee, Pacific Science Board, National Research Council, in co-operation with the U.S. Navy.

Natural enemies found included amongst the Vertebrata a mongoose-like animal of the family Viverridae, identified as *Bdeogale tenuis* Thomas & Wroughton and certain Rodentia. Among the Crustacea a land crab was observed feeding on *Achatina* snails close to the

coast. Important enemies were carnivorous snails of the family Streptaxidae, notably *Edentulina affinis* C.R. and *Gonaxis kibweziensis* E.A. Smith. Certain snails of the genus *Gulella* were also observed as predators. Of the insects, a carabid beetle *Tefflus* sp., drilid beetles and certain Lampyridae were also considered factors in the complex of *Achatina* control in Africa.

Two species of carnivorous snails, the *Tefflus* beetle and a drilid beetle in the larval stage, were brought to Honolulu in small numbers for further study in quarantine. Their possible effect on non-economic snails will be considered before decision is made respecting their liberation in Micronesia.

Note.—The above is an abstract of a Bulletin to be published later by the Museum of Comparative Zoology, Harvard University.

BIOLOGICAL CONTROL OF INSECTS AND PLANTS IN FIJI

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Introduction

Biological control of insects and weeds has been singularly successful in the Fiji Island, where the amount of work done along these lines has been considerable, having regard to the size and the resources of the group. The reasons which may be assigned for the success achieved are as follows:

(a) The restricted nature of the island fauna, which offers little competition to introduced species, compared with that which they would encounter in continental areas.
(b) The favourable climate, which permits of growth and reproduction throughout the year.
(c) The concentration, by a team of efficient workers, on biological control of the insect pests of a single crop, the coconut palm.
(d) The comparatively large expenditure, by a small community, which made the work possible.

In passing, it may be remarked that the method of biological control is particularly valuable as a weapon against insect pests of the coconut palm in the South Pacific islands, quite apart from the fact that ecological conditions are well suited to its practice. In normal times, coconuts are a crop of low value per acre, and the cost of spraying or dusting them is heavy, as the work would call for power machines or aeroplanes. Moreover, many of the island peoples, such as the Melanesians of Papua, New Guinea, and the Solomon Islands, are very backward, and not in a position to finance or efficiently implement artificial control measures. Hence a greater concentration on biological means of control is justified than would be the case in more advanced countries.

In this paper it is proposed to present a short history of biological control work in Fiji, and then to deal in greater detail with the more outstanding campaigns, and to comment on points of particular interest.

History

In 1911 the Government Entomologist, Mr. Frank P. Jepson, introduced from Hawaii the Lantana Seed Fly, *Agromyza lantanae* Frogg., which rapidly became established on *Lantana camara* in Fiji (5). In

1912 the Colonial Sugar Refining Company sent Mr. D. S. North to Hawaii to import colonies of the Tachinid *Microceromasia sphenophori* Vill., a parasite of the weevil borer of sugar cane, *Rhabdoscelus obscurus* Boisd. Further introductions of this parasite from Hawaii were made in 1913 by Professor J. F. Illingworth (3) of Honolulu, and in 1917 by Mr. R. Veitch, of the Colonial Sugar Refining Company (34). Breeding and distribution of the insect was carried on by the Company for years. The parasite was then found to be established in the field, but has not been a spectacular success. Its effect on the incidence of the weevil has never been thoroughly evaluated, though Veitch (34) considered that the parasite had been responsible for a reduction in damage by the weevil in the Nausori area.

In 1913 Jepson went to Java in search of natural enemies of the Banana Weevil Borer, *Cosmopolites sordidus* Germ. (4), and decided to import the Histerid predator, *Plaesius javanus* Er. As the beetles survive for several months without food, if kept in moist soil, no great difficulty was experienced in transporting them to Fiji. Several thousand were liberated, and began to reproduce in the field, larvae and pupae being found several months later. Nothing was then seen of the predator for several years. In 1918 a further supply of 163 beetles arrived from Java by post, packed in sphagnum moss. In 1921 *P. javanus* was recovered in the field (18), and subsequently it became well established on the island of Viti Levu.

In 1917, Veitch introduced the Scoliid wasp, *Scolia manilae* Ashm., as a parasite of whitegrubs attacking sugarcane. Five years later this wasp was found to be established in the field (35).

In 1920 and 1921, Mr. H. W. Simmonds, Government Entomologist, travelled to Tahiti to obtain parasites of the scale insect *Aspidiotus destructor* Sign., and brought back *Aphytis chrysomphali* Mercet and *Aspidiotiphagus citrinus* Craw. (16 & 17). In 1922 and 1923, Simmonds introduced from Hawaii the butterflies *Thecla echion* L., and *Thecla bazochii* God., parasites of *Lantana camara* (19).

The first spectacular success of biological control in Fiji was the suppression of the Levuana Moth, *Levuana iridescens* B-B., by the Tachinid parasite *Ptychomyia remota* Ald. (33). This Zygaenid moth was threatening the existence of the coconut industry, and in 1924 a committee was formed to organize action against the pest. Known as the Levuana Committee, and later as the Coconut Committee, it employed Mr. A. M. Lea to investigate parasites of the moth in Malaya, and shortly afterwards Dr. J. D. Tothill and Messrs. T. H. C. Taylor and R. W. Paine were appointed to the staff. As a result of the work of these three entomologists, assisted by Simmonds, complete control of *Levuana iridescens* was accomplished by 1928.

Meanwhile, in 1924, Lea had introduced several species of ladybird beetles, including *Cryptolaemus montrouzieri* Muls., and the lacewing *Chrysopa ramburi* Schreider, from Australia (24). Paine and Taylor brought from Hawaii, in 1925, a number of species of parasitic Hymenoptera (33).

In 1927 and 1928 Taylor and Paine worked on the control of *Aspidiotus destructor,* a serious pest of the coconut palm. Paine studied the pest and its parasites in Fiji, while Taylor went to Java and Trinidad in search of natural enemies (31). From Java he imported four species of internal parasites and two predators, *Scymnus* sp. and

Aleurodothrips fasciapennis Frankl. From Trinidad were brought five species of Coccinellids, and one of these *Cryptognatha nodiceps* Mshl., registered another overwhelming success, so that eighteen months after its introduction, *Aspidiotus destructor* was very hard to find.

In 1928, Simmonds visited Hawaii and brought back the bug *Teleonemia scrupulosa* Stal., a parasite of *Lantana camara* (20). The bug quickly established itself in the field, and has since exercised some degree of control on *Lantana*, though checked by attacks of the Lygaeid *Germalus pacificus* Kirk., and by heavy rainfall (2 & 21). In 1929, Simmonds imported the dung-beetle *Copris incertus* var. *prociduus* Say. (22), which has since become very well established.

In 1929, Paine went to Java to investigate the possibility of introducing parasites of the Coconut Spike Moth, *Tirathaba trichogramma* Meyr., and Simmonds travelled to Trinidad to bring back colonies of *Liothrips urichi* Karny, for the control of the weed *Clidemia hirta*. Its introduction to Fiji had been recommended by Taylor, who had studied its biology while in Trinidad in 1927-28 (28). The introduction of the thrips in 1930 proved an outstanding success, and the weed is no longer troublesome in Fiji (25). Paine's investigations in Java, covering a period of eighteen months, were most skilfully conducted, but unfortunately have never been published in full. The only published reference to this work is contained in a Bulletin of the Department of Agriculture, Fiji (15). In 1930, Taylor, who had made a detailed study of *T. trichogramma* in Fiji (29), brought back *Apanteles tirathabae* Wilk., which rapidly established itself in the field. Paine continued his studies in Java, and in 1931 returned to Fiji with colonies of an egg parasite, *Tetenomus tirathabae* Ferr., and a Tachinid, *Erycia basifulva* Bezzi. In 1933 he returned to Java, and brought back colonies of *Erycia basifulva* and another parasite, *Nemeritis palmaris* Wilk. All these parasitic species became established in the field (15). Paine also introduced the predatory mosquitoes *Megarhinus splendens* Wied., from Java, and *M. inornatus* Walk., from Rabaul (14).

While in Java, Paine had made a preliminary study of the parasites of the leaf-miner *Promecotheca nuciferae* Maulik, as an allied species, *P. reichei* Baly, was a severe pest of the coconut palm in the Lau group of islands in Fiji. In 1931, Taylor went to Java to carry on the investigation, and the result of his work was the introduction to Fiji of the Eulophid *Pleurotropis parvulus* Ferr., in 1933. Another remarkable success resulted, complete control of the pest being brought about with great rapidity. This campaign is fully dealt with in Taylor's excellent treatise on the subject (32). At the same time, Taylor introduced a species of *Cremastus*, a parthenogenetic parasite of the Banana Scab Moth, *Lamprosema octasema* Meyr. (30).

In 1935, Simmonds introduced two species of Fruit Fly parasites from Hawaii, *Tetrastichus giffardianus* Silv., which quickly became established in the field, and *Opius humilis* Silv., of which only one small colony was released (27). In the same year, a strong colony of *Cremastus flavoorbitalis* Cam., a parasite of Pyralids, was introduced from Hawaii and released (26). According to information supplied by the Colonial Sugar Refining Company, three species of beneficial insects were introduced by their staff from Hawaii during 1936. These were *Anagyrus saccharicola* Timb., a parasite of the sugarcane mealybug, *Trionymus sacchari* Ckll., and two enemies of the weed *Cyperus rotundus* L. namely the moth *Mactra truculenta* Meyr., and the weevil *Athesapeuta cyperi* Marsh. Further fruit-fly parasites introduced were *Dirhinus* sp. from India in 1937 (6 & 13) and *Melittobia indicum* Silv. from New South Wales in 1938 (7). In 1938 also, a large consignment of the Histerid *Pachylister chinensis* Quens., was sent from Java by Simmonds for housefly control (8). In 1941, R. A. Lever, who succeeded Simmonds as Government Entomologist in 1938, introduced *Microphanurus basalis* Woll., an egg-parasite of *Nezara viridula* L. (10), and in 1943 *Diadromus collaris* Grav., a parasite of *Plutella maculipennis* Curt., was imported from New Zealand (11).

A list of the parasites and predators imported into Fiji is presented as an appendix. This list is based on those compiled by Simmonds(24) and Lever (9).

NOTABLE CAMPAIGNS

(a) *Levuana iridescens* B-B.—It is proposed to describe some of the more outstanding work done in the field of biological control in Fiji, and the first campaign to be considered is that against the Levuana Moth, *Levuana iridescens* B-B. This account is taken from "The Coconut Moth in Fiji", by Tothill, Taylor & Paine.

The first definite record of the occurrence of the pest was made in 1877, when a caterpillar was observed to be causing severe damage to the foliage of coconuts on the main island of Viti Levu. The larva feeds on the underside of leaflets of the coconut palm, the green tissue being removed from between adjacent veins, causing characteristic longitudinal scars. During severe outbreaks, palms might be almost completely defoliated, so that the nuts failed to mature, a constriction occurred in the trunk, and death of the tree might result.

Severe outbreaks occurred from time to time on Viti Levu, but as coconuts were not grown commercially on this island, the economic loss was not great. However, when the pest began to spread, about 1918, to the islands east of Viti Levu, there was great consternation. Rigid quarantine measures were adopted, to prevent its further spread, and considerable numbers of coconuts were felled near the port of Levuka. In 1924 the Levuana Committee, referred to above, was formed, financed by a tax of 2/6 per ton on copra, and an equal contribution from the Fiji Government.

In June, 1923, Mr. H. W. Simmonds, the Government Entomologist, was sent on an eight months' tour of the New Hebrides, Bismarck Archipelago, Solomon Islands and New Guinea. The purpose of the tour was to seek the native habitat of *Levuana,* which had no known parasites in Fiji, and appeared to be an introduced insect. Simmonds failed to find the insect, nor has it yet been observed outside Fiji.

The Levuana Committee then sent Mr. A. M. Lea and an assistant to Java and Malaya, to attempt the introduction of parasites known to occur on the allied Zygaenid, *Artona catoxantha* Hamps. Two shipments of parasites were made from Java, but failed to survive the journey.

Dr. Tothill and Messrs. Taylor and Paine arrived in Fiji in 1925, and Taylor was sent on a tour of New Guinea and New Britain, to continue the search for the native home of *Levuana iridescens*. He did not find the insect, but observed four species of allied Zygaenids, whose larvae fed in a manner similar to that of *Levuana*. Several species of parasites occurred, but hosts and parasites were both so rare that no attempt was made to introduce the latter to Fiji.

Meanwhile, Simmonds had been sent to Malaya to await an outbreak of *Artona catoxantha*, when it was hoped that sufficient parasitized larvae could be obtained to provide strong colonies for shipment. It had been decided to attempt the introduction of the Tachinid *Ptychomyia remota* Ald. and the Braconid *Apanteles artonae* Rohw., which appeared to be the main controlling agents in Malaya. As *Artona* was normally a rare insect, it was necessary to await one of its occasional localized outbreaks. Taylor arrived in Malaya on his way to Cochin China, continuing his search for the home of *Levuana*, and his arrival coincided with an outbreak of *Artona*. He remained in Malaya to assist Simmonds in the collection and shipment of parasitized material. The transporting of *Ptychomyia remota* to Fiji was successfully carried out, and the Clerid beetle *Callimerus arcufer* Chapin, was also brought in. All the *Apanteles* died before the completion of the journey. The Tachinid, freed from hyperparasites which attacked it in Malaya, brought about complete suppression of its host in a very short time.

Apart from the fact that the *Levuana* campaign was extremely successful, there were associated with it some phenomena of peculiar interest. There is the unsolved question of the native habitat of *Levuana iridescens*. As has been stated above, search in the Solomon Islands, New Guinea, New Britain and the New Hebrides failed to reveal its presence. Indo-China was considered a possibility, as ships in the sandalwood trade used to ply between there and Fiji during the last century, but no search was made there because of the success of *Ptychomyia*, and because later work indicated that the Solomon Islands or the New Hebrides were more likely habitats. It was in the Solomons that the species most closely allied to *Levuana* was found.

On the other hand, all the evidence indicated that *Levuana* was not a native of Fiji. Before the introductions from Malaya, there were no parasites of the moth in Fiji, though all the allied species of Zygaenids found in the Solomon Islands and the New Guinea region were rare and heavily parasitized. Also, until about 1918, the moth was not found outside the island of Viti Levu. Finally, Taylor points out that *Levuana iridescens* is as specialized as the closely related Zygaenid found in the Solomon Islands, and more specialized than *Artona*, which is a native of Asia. As the insect fauna of both Asia and the Solomons is very rich compared with that of Fiji, an insect native to Fiji would be expected to be less specialized than its relatives from Asia and the Solomon Islands. It was finally concluded that *Levuana iridescens* was probably introduced from the Solomons or New Hebrides, possibly in the form of pupae on the leaves of the host plant.

An interesting study arising from the *Levuana* campaign was that made by Simmonds of the moth *Artona catoxantha* in Malaya (23). Normally it is a rare insect, and very difficult to find, but occasionally, during a dry season, it occurs in epidemic form in very localized areas, perhaps only a few acres in extent. These few acres may be almost completely defoliated, while areas of palms in the immediate vicinity are undamaged. During these severe outbreaks, there is not the complete overlapping of generations which one commonly finds among insects in tropical countries. The greatest difference in age between the stages of the life-history found by Simmonds at any given time was twenty days, and this condition continued through succeeding generations of *Artona*. Epidemics were normally brought to a close by the advent of the rainy season. Another phenomenon was that, though the duration of one generation of *Artona*, from egg to egg, is about 35 days, during outbreaks a period of about 45 days occurred between the mass appearance of any given stage of the insect.

This state of affairs was explained by Simmonds as being due to the activities of *Ptychomyia*, which was by far the most common parasite during outbreaks. Normally the Tachinid lays its eggs on fourth-instar larvae, and its life-history from egg to egg occupies 19 to 20 days. When a brood of caterpillars from an individual lot of *Artona* eggs is attacked by *Ptychomyia*, the adult flies emerge at about the same time as the moths, which are produced from unparasitized caterpillars. Where all stages of *Artona* are present, the parasites would oviposit on fourth-instar larvae from an earlier batch of eggs. However, under epidemic conditions, the flies multiply rapidly, and the stage is reached where practically all fourth-instar larvae are killed. This creates a break in the overlapping of generations, and causes an extension of the time between mass incidence of any given stage of the host in the field. Consequently, when a batch of adult parasites emerges, there are no suitable hosts available, and the fly has to wait for them, when it deposits its eggs eagerly, and considerable superparasitism occurs. (This does not greatly affect the reproduction of the parasite, as one healthy individual emerges from a host which has been superparasitized.) The parasites are so numerous and so eager to lay that all fourth-instar larvae are again killed, and so the break in generations is perpetuated.

Simmonds states that the same phenomenon was observed with *Levuana iridescens* in Fiji in three localities only. These were all isolated groups of coconuts, two of them on small islands. There seems little doubt that the break in generations is due to localization of the host in a small area. Where larger areas are involved, the adult parasites, which have strong powers of flight, would be able to go far afield to find hosts at a suitable stage of development. In the case of *Artona catoxantha*, Corbett (1) advances a hypothesis to explain the localized nature of the outbreaks. His opinion is that the moth's normal habitat is the jungle, and that occasional flights of moths are carried by wind to restricted areas of coconuts, causing heavy infestation in a small area.

(b) *Aspidiotus destructor*.—A full account of the campaign against the scale insect, *Aspidiotus destructor* Sign., has been given by Taylor.(31) The following remarks have been extracted from this publication. The scale, which is widely distributed throughout the tropics, attacks a great variety of host-plants, and can be very injurious to coconut palms and bananas. In Fiji it was first reported as a pest of bananas, and later became a serious pest of coconuts. By 1920, its spread among coconut plantations had caused alarm, so that quarantine measures were instituted to prevent its further dissemination among the islands of the Fiji Group. As was mentioned earlier, Simmonds was sent to Tahiti to introduce parasites. However, during the next few years the pest continued to increase in numbers and distribution, and by 1927 was the most serious pest of the coconut palm in Fiji. During epidemic outbreaks, the whole of the lower surface of the coconut leaflets might be covered by a yellow crust of scales, and defoliation and even death of palms frequently resulted.

In 1926, Taylor investigated the parasites and predators of *Aspidiotus destructor* and the allied *Aspidiotus palmae* in Java, and early in 1927 colonies of various species of parasites and predators were shipped to Fiji (see Appendix). However, they did not exercise any significant controlling effect, though the Coccinellid *Scymnus* sp. became established in the field. In 1928, Taylor proceeded to Trinidad, to investigate various species of Coccinellids which were known to attack *Aspidiotus destructor*. As a result, five species of Coccinellids were shipped to Fiji, arriving there in March, 1928.

It was soon evident that *Cryptognatha nodiceps* Mshl. was by far the most efficient of the predators, so that after the first six months, breeding of the others was discontinued. *Cryptognatha* was liberated on all the islands where *Aspidiotus* occurred, in colonies of 100 to 500, and its controlling effect was remarkable. Taylor states that within nine months of the arrival of the shipment in Fiji, the scale had been brought under control in the more important islands, and after eighteen months *Aspidiotus* was, in many areas, very difficult to find.

Taylor lists the attributes of *Cryptognatha* which explain its great efficiency. Among these are its great voracity, its concentration on *Aspidiotus destructor* as a host, its long adult life, high reproductive capacity, and great powers of dispersal. He then makes some interesting comments on the relative efficiency of parasites and predators as controlling agents for *Aspidiotus destructor*. In Fiji, this scale occurred in irregular outbreaks of great severity, with which local parasites and predators were unable to cope. When the leaves of a palm reached the stage of being completely covered by scales, emerging larvae wandered over the leaves in countless thousands, seeking a place to settle down. Great numbers perished, but many managed to be conveyed to neighbouring palms on the bodies of passing birds and bats. In this way the infestation could spread rapidly, and to prevent this spread a parasite or predator had to be capable of suppressing the pest before the leaves became covered with scales. Taylor considers that only a predator like *Cryptognatha*, of great voracity and a reproductive potential comparable to that of its host, could fulfil the requirements. A parasite with a reproductive rate similar to that of the host could not catch up with an outbreak, as each parasite destroys only one host individual, compared with the hundreds devoured by an efficient predator.

Taylor's conclusion is that, to control a scale insect which occurs in irregular and severe outbreaks, one should seek predators, and that the qualities necessary for success in the predator are great voracity and an egg-production and length of life-cycle comparable to that of its host.

(c) *Tirathaba trichogramma* Meyr.—In 1929 Taylor investigated the problem of early nutfall from coconut palms in Fiji, and published his results in the form of a Bulletin issued by the Department of Agriculture (29). He concluded that the main cause of nutfall was the work of the Pyralid moth, *Tirathaba trichogramma* Meyr., and that copra production could be increased by over 30 per cent if this insect were eliminated. He stated that certain favourably situated female flowers on each spike were destined to remain on the spike and reach maturity, whereas other flowers and young nuts were destined to fall early. Whenever attack by *Tirathaba* larvae—which bore into male and female flowers—caused the fall of female flowers which had been destined to reach maturity, a reduction in yield was caused.

Corbett, in Malaya, as the result of lengthy investigation of the allied moth, *Tirathaba rufivena* Walk., had concluded that it had no effect on premature nutfall, and Paine (15) expressed doubt as to whether *T. trichogramma* caused any significant reduction in yield in Fiji. However, as a result of Taylor's findings, it was decided to attempt the control of *Tirathaba* by introducing parasites of the allied *T. rufivena* and *T. mundella* from Java. Hence, in 1929, Paine went to Java, where he carried out investigations covering a period of 18 months on the pest species and their parasites. Apart from the data presented in a Bulletin of the Fiji Department of Agriculture (15), the account of the excellent work done by Paine during this period exists only in manuscript. The following account is taken from the abovementioned Bulletin.

Paine found numerous parasites of *Tirathaba* in Java, of which three species were important and widely distributed. These were the Scelionid, *Telenomus tirathabae* Ferr., an egg-parasite, the Braconid, *Apanteles tirathabae* Wilk., and the Tachinid *Erycia basifulva* Bezzi, the two latter being parasites of the larva. *Apanteles* appeared to be the most promising, as it was the most effective parasite in Java, despite its being attacked by hyperparasites. In February, 1930, Taylor took colonies of *Apanteles* to Fiji, and the parasite, freed from its secondary parasites, rapidly became established in the vicinity of Suva, and attacked a higher percentage of *Tirathaba* larvae than it had done in Java.

After further study in Java, Paine found that *Erycia basifulva* did not compete with *Apantales,* as it attacked more mature larvae, and early in 1931 he brought colonies of the Tachinid and of *Telenomus* to Suva. *Telenomus* was later recovered in the field, but in June the breeding stock of *Erycia* died out, after two large colonies had been liberated. By the end of 1932, the introduced parasites showed little evidence of bringing their host under control, so it was decided to reintroduce *Erycia basifulva,* and to import an Ichneumonid parasite of the larva, *Nemeritis palmaris* Wilk., which occurred in small numbers in Java, and was an important parasite of *Tirathaba rufivena* in Malaya. Paine again visited Java, and in May, 1933, arrived in Fiji with colonies of *Nemeritis, Erycia,* and another species of Tachinid, *Sturmia painei* Baran. The *Sturmia* colony died out, after only a few adults had been liberated at Lautoka, but breeding and distribution of *Nemeritis* and *Erycia* proceeded satisfactorily, and both became established in the field.

As mentioned above, much of Paine's work on *Tiranthaba* and its parasites has not been published, but he has given me permission to make use of his manuscript, from which the following notes on the bionomics of *Erycia* and the ingenious technique employed in breeding it, have been abstracted.

The fly is apparently a coconut-frequenting species, as it attacks only those species of *Tirathaba* which feed on coconut palms. It is a strong flier, and will not mate readily in captivity. Oviposition commences nine or ten days after mating, and during this period the eggs descend from the ovaries into the uterus, which becomes greatly distended with four or five thousand microtype eggs. The female fly now seeks coconut flowers where larvae of *Tirathaba* are feeding, and among these flowers she scatters her eggs, which adhere to the surface on which they fall.

The eggs do not hatch until swallowed by a host caterpillar, and meanwhile can retain their vitality, under humid conditions, for up to 13 days. When the maggot is fully fed, it pupates within the cocoon of the host. The adult fly emerges from the puparium during the morning, usually between 9 a.m. and 1 p.m. The flies are stimulated by sunshine, and mating in cages is rarely attempted on sunless days. When kept in glass jars, and fed regularly with honey-water, they lived as long as three weeks, but in cages their life was shorter, partly owing to damage sustained by striking the walls of the cage, and partly because they failed to find the water provided for them in the cages.

The main difficulties associated with breeding the parasites were their unwillingness to mate in a confined space, and the necessity to keep the females alive for at least eight days after mating, so that their eggs might descend into the uterus and mature. Moreover, though mated females would oviposit readily in glass jars or tubes, only a small percentage of the eggs were eaten by caterpillars. To cope with these difficulties, Paine evolved the following breeding technique:

For mating purposes, the smallest suitable cage was about six feet high, six feet long and three feet six inches wide. The basal portion was of wood, and the roof and upper portions of the walls were of wire gauze. Better illumination, without an undue rise in temperature, could be obtained by using calico shades outside the cage, with a wide air-space between gauze and calico. Food consisted of sponges soaked in diluted honey and water, and suspended from the roof, and pieces of loaf sugar. Male coconut flowers, and numerous *Tirathaba* larvae were placed on a wooden shelf, built about three feet from the floor, at the end of the cage opposite the door, and where possible, fresh flowers were added daily. The flowers and larvae seemed to provide an additional stimulus for the flies to mate, and to accelerate the passage of eggs from the ovaries to the uterus. During sunny days, the flowers were sprayed with water at least three times each day, and in all weather it was necessary to moisten the flowers when the cage was first visited in the morning. A shelter was placed over the cage to keep off heavy rain.

From fifty to one hundred flies could be placed in a cage of the size described, but the percentage of matings of female flies never reached fifty. However, at least 10 per cent of female flies usually mated and lived long enough for the eggs to mature, thus providing an ample supply of viable eggs. The females were left in the cage for five or six days, after which they were removed to a glass jar and fed with honey-water. Here they were kept until they died, after which they were dissected, and the uterus removed from each individual. If some of the eggs in a uterus were not mature, they would continue to develop if the unbroken uterus, freed from all adhering tissues, were kept in a moist atmosphere. This was accomplished by placing the uterus on the underside of the lid of a small glass pot, in which was kept a small plug of cotton wool, well soaked in water. Embryos were known to be mature when the black mouth-parts could be seen within the egg.

The next step was to place mature eggs in water on a glass slide, forming a "smear", and, using a low-power binocular microscope, transfer them with a fine brush to male coconut flowers. A thin slice was cut from the base of each flower with a sharp, stainless-steel knife, thus leaving a flat, moist surface, to which the eggs adhered when the brush, carrying the eggs, was drawn across the surface. Two flowers, carrying the eggs, were placed in a glass tube, with a single *Tirathaba* larva, early fifth-instar larvae being preferable, and fourth- or even third-instar larvae giving better results than late fifth-instar. Larvae about to moult were not used. The tubes were then stacked, stoppered-end up, and left overnight. By the following day, most of the larvae had eaten through the base of the flowers, and swallowed some of the eggs. When two eggs were placed on each flower, as high as 65 per cent of parasitism resulted, but when mature eggs were abundant, from six to ten were placed on each flower, and over 90 per cent of the larvae were parasitized. After swallowing the eggs, the larvae were fed with male flowers until they pupated.

(d) *Promecotheca reichei* Baly.—The campaign which led to biological control of this insect is described by Taylor in an excellent publication of the Commonwealth Institute of Entomology (32), from which the following notes have been abstracted.

P. reichei feeds on the coconut palm, the larvae mining within the leaflets, and the adults feeding on the leaf tissue. Though present throughout Fiji, it caused severe damage mainly in the comparatively dry Lau group of islands, intermittent outbreaks of great severity causing a great reduction, or even cessation, of nut-production by the palms. Local parasites of the egg and larva were capable of controlling their host under the normal condition of completely overlapping generations. Where overlapping was greatly restricted, they were unable to prevent outbreaks, and hence Taylor sought in Java a parasite which would be capable of suppressing the pest under such conditions. His quest was successful, and in 1933 he introduced the Eulophid *Pleurotropis parvulus* Ferr., which was one of a number of parasites of *Promecotheca nuciferae* Maulik, discovered by Paine while he was studying *Tirathaba* spp. *P. parvulus* proved to be another remarkably successful introduction, bringing about complete control of its host in individual areas within a few months of liberation.

The study of the work of controlling *P. reichei* is of particular interest for two reasons, first the break in overlapping of generations, and second the necessity to find a parasite with specific qualities required under local conditions.

Taylor points out that multiple-stage outbreaks of the pest, that is, with completely overlapping generations, occurred at times, due to fluctuations in the balance between the pest and local parasites, to introductions of the pest, without its parasites, to new localities, and to destruction of the parasites by hurricanes. Usually such outbreaks were very localized, and of small consequence, except in the case of those caused by hurricanes, which could be quite extensive and severe. One-stage outbreaks were caused by the intervention of the mite *Pediculoides ventricosus* Newp., in a multiple-stage outbreak. This came about as follows: The conditions required by the mite are that the *P. reichei* individuals should be crowded together, and the weather dry, as heavy rains drastically reduce the mite population. Crowding of *P. reichei* occurs even in a multiple-stage outbreak confined to a few palms, because the beetle is gregarious, and does not spread until forced to do so by lack of food. When the mite finds a crowded colony of *Promecotheca* at the beginning of the dry season, conditions for its multiplication are ideal. It enters the larval mine through the slit made by the newly-hatched larva, and attacks larvae, pupae, and newly-emerged adults, penetrating the integument of its victim with its mouth-parts, and sucking out the body fluids. In a very short time all stages of the host except eggs and adults are destroyed, so that food for the mites becomes very scarce, though they can feed for about two weeks on the remains of their dead hosts. The longevity of the adult beetle is about a month, during the last fortnight of which the female lays its eggs. (Other approximate life-history figures are: Incubation, 19 days; larval period, 50 days; pupal period, including pre-emergence resting period of adult, 20 days.) Consequently, the stage is reached when the numbers of the mite have been drastically reduced, and the difference in age between the oldest and youngest surviving larvae of *P. reichei* is about two weeks. These larvae are then the only stage of the beetle in the field.

Towards the end of the larval stage, and during the pupal stage, the population of mites again begins to increase, but not sufficiently to have much effect on the next generation of beetles, so that there is a very great increase in population of the latter. At the end of this second generation, the mite is again very numerous, and parasitism of the later pupae reaches practically 100 per cent. Hence the period during which beetles emerge from the mines is restricted to about ten days. The two generations of the beetle have occupied about six months, and the wet season now sets in. The mites die off in great numbers, as only eggs and adults of the host are present, and they are unable to build up during the wet season. A very numerous brood of beetles emerges during the middle of the wet season, the emergence period covering about a month, and vast numbers of eggs are laid over a period of about 5½ weeks. The local egg-parasite, *Oligosita utilis* Kow., now steps in, and by parasitizing 100 per cent of the earlier batches of eggs, reduces overlapping to about three weeks. By the time that the fourth generation of beetles is emerging, the dry season has again set in, and the mite takes over once more. Hence we have the phenomenon of parasites—primarily the mite and secondarily the egg-parasite—producing conditions which make control of a pest by local parasites impossible.

As a result of his study of the cause of one-stage outbreaks, and the reasons for the ineffectiveness of local parasites, Taylor listed seven desirable attributes for a parasite which would be able to control *P. reichei* under the existing conditions. They were as follows:

(1) It must attack larvae of all ages, and also pupae. This would probably allow time for three generations of the parasite during one of the host, and would reduce the period when no

hosts were available to about three weeks. The local larval parasite, *Elasmus hispidarum* Ferr., did not attack pupae and consequently had to survive a period of about six weeks without hosts.

(2) It must be an internal parasite. It would then probably avoid attack by the secondary parasite, *Tetrastichus taylori* Ferr., which reduced the value of the external parasite, *E. hispidarum*. Also it would be less exposed to attack by the mite.

(3) Its adult life must be at least three weeks, to tide it over the period when hosts were not available.

(4) One generation must not cover more than one month, thus allowing three generations of the parasite to one of the host.

(5) Its biotic potential must be not less than 20.

(6) It must be very active, and capable of rapid spreading.

(7) It must not be adversely affected by the climatic conditions of Fiji.

Of the parasites available in Java, *Pleurotropis parvulus* most closely fitted these requirements, and hence was selected by Taylor, even though it was comparatively rare. *Dimmockia javanica* Ferr., the most successful parasite under Javanese conditions, and *Pleurotropis painei* Ferr., a pupal parasite, were also brought to Fiji, but as had been expected, proved useless under the conditions of a one-stage outbreak. The success of *P. parvulus*, however, proved a fitting sequel to a very pretty example of entomological detective work.

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APPENDIX

LIST OF BENEFICIAL INSECTS INTRODUCED INTO THE FIJI ISLANDS

Year	Beneficial Species	Host Species	Introduced From	Remarks
1911	Agromyza lantanae Frogg.	Lantana camara L.	Hawaii	Well established
1912 1913 1917	Microceromasia sphenophori Vill.	Rhabdoscelus obscurus Boisd.	,,	Established
1913 1918	Plaesius javanus Er.	Cosmopolites sordidus Germ.	Java	Established; exercises considerable control of host
1917	Scolia manilae Ashm.	Rhopaea vestita Arrow. Rhopaea subnitida Arrow. Adoretus versutus Har.	Hawaii	Established
1920 1921 1927	Aphytis chrysomphali Mercet	Aspidiotus destructor Sign.	Tahiti Java	Established
1920 1921	Aspidiotiphagus citrinus Craw.	,,	Tahiti	Established
1922 1923	Thecla echion L.	Lantana camara L.	Hawaii	
1923	Thecla bazochii God.	,,	,,	Established
1924	Orcus australasiae Boisd.	Diaspine scales	Australia	
,,	Orcus chalybdeus Boisd.	,,	,,	
,,	Leis conformis Boisd.	Aphids	,,	
,,	Cryptolaemus montrouzieri Muls.	Mealybugs	,,	Established
,,	Chrysopa ramburi Schreider	Various	,,	
1925	Ptychomyia remota Ald.	Levuana iridescens B-B.	Malaya	Completely controls host
,,	Callimerus arcufer Chap.	,,	,,	
,,	Trichogramma pretiosa Ril.	Various	Hawaii	
,,	Chalcis obscurata Walk.	,,	,,	
,,	Ecthromorpha maculipennis	,,	,,	
,, ,,	Frontina archippivora Will.	,,	,,	

Year	Beneficial Species	Host Species	Introduced From	Remarks
1925	Casinaria infesta Cress.	Various	Hawaii	
,,	Chelonus blackburni Cam.	,,	,,	
,,	Euplectrus platyhypenae How.	,,	,,	Established
1925 1928	Microbracon omiodivorum Terry.	,,	,,	
1927	Trichogrammatoidea nana Zehnt.	,,	Java	Established; already in Fiji
,,	Chalcid sp.	Levuana iridescens B-B.	,,	
,,	Scymnus sp.	Aspidiotus destructor Sign.	,,	Established
,,	Spaniopterus crucifer Gahan	,,	,,	
,,	Comperiella unifasciata Ishii.	,,	,,	
,,	Casca parvipennis Gahan	,,	,,	
,,	Aleurodothrips fasciapennis Frankl.	,,	,,	
1928	Cryptognatha nodiceps Mshl.	,,	Trinidad	Completely controls host
,,	Cryptognatha simillima Sic.	,,	,,	Established
,,	Azya trinitatis Mshl.	,,	,,	
,,	Scymnus aeneipennis Sic.	,,	,,	
,,	Azya luteipes Muls.	Lecanium spp.	Hawaii	
,,	Teleonemia scrupulosa Stal.	Lantana camara L.	,,	Established
,,	Spalangia cameroni Perk.	Housefly	,,	
1929	Copris incertus var. prociduus Say.	Dung-burying Beetle	,,	Established
1930	Liothrips urichi Karny	Clidemia hirta D. Don	Trinidad	Excellent control of host
,,	Apanteles tirathabae Wilk.	Tirathaba trichogramma Meyr.	Java	Established

Year	Beneficial Species	Host Species	Introduced From	Remarks
1931 1933	Erycia basifulva Bezzi	Tirathaba trichogramma Meyr.	Java	Established
,,	Telenomus tirathabae Ferr.	,,	,,	Established
1931	Megarhinus splendens Wied.	Mosquitoes	,,	Established
,,	Mesembrina meridiana L.	Housefly	England	
1933	Pleuretropis parvulus Ferr.	Promecotheca reichei Baly.	Java	Established; completely controls host
,,	Cremastus sp.	Lamprosema octasema Meyr.	,,	
,,	Megarhinus inornatus Walk.	Mosquitoes	New Britain	
,,	Nemeritis palmaris Wilk.	Tirathaba trichogramma Meyr.	Java	Established
,,	Sturmia painei Baran.	,,	,,	Only a few adults liberated
1935	Tetrastichus giffardianus Silv.	Fruit flies	Hawaii	Established
,,	Opius humilis Silv.	,,	,,	
,,	Cremastus flavo-orbitalis Cam.	Pyralidae	,,	
1936	Anagyrus saccharicola Timb.	Trionymus sacchari Ckll.	,,	
,,	Bactra truculenta Meyr.	Cyperus rotundus L.	,,	
,,	Athesapeuta cyperi Marsh.	,,	,,	
1937	Dirhinus giffardii Silv.	Fruit flies	India	
1938	Melittobia indicum Silv.	,,	Australia	
,,	Pachylister chinensis Quens.	Housefly	Java	Established
1941	Microphanurus basalis Woll.	Nezara viridula N.	Australia	Established
1943	Diadromus collaris Grav.	Plutella maculipennis Curt.	New Zealand	

BIOLOGICAL CONTROL OF WEEDS

THE INITIATION OF THE BIOLOGICAL CONTROL OF WEEDS IN THE UNITED STATES

By Harry S. Smith, Division of Biological Control, University of California

[Abstract]

Biological control of weeds has been practised regularly and successfully by agricultural scientists of Australia and New Zealand for many years. An ultra-conservative policy in the United States regarding this method of weed control has been abandoned and work is now under way, having as its objective the control of the weed *Hypericum perforatum* and the shrub *Ulex uropaeus* in California and other states on the Pacific Slope with considerable promise of success. The Chrysomelid beetles *Chrysomela hyperici* and *C. gemellata* have been introduced from Australia and are making excellent progress on the ranges. Starvation tests are being conducted on *Apion ulicis*, imported from England, for possible introduction against *Ulex*. It is predicted that these efforts will be followed by attempts to control other weed pests, particularly on range lands, by this method.

SOME ASPECTS OF THE CONTROL OF WEEDS BY INSECTS

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My purpose here is not to attempt a general review of the problems or principles involved in the entomological control of weeds, but to focus attention on several selected aspects which seem to be of importance, and which are perhaps insufficiently appreciated.

Despite several remarkable successes that can be credited to the entomological method of weed control (one need mention only Prickly Pear in Australia and *Clidemia hirta* in Fiji), it seems that the efficacy of the method and its scientific soundness has yet to be accorded full recognition by entomologists, and that the time has yet to come when all those concerned with weed control will regard the entomological method as one which is as valid under suitable circumstances as are the chemical and cultural methods under circumstances appropriate to their use.

The doubts that some entomologists feel about the value of entomological control as applied to weeds have presumably decreased as its efficacy has been demonstrated empirically in the field, but I do not think that these doubts by any means have been dissipated completely.

On what is this scepticism based? Partly, in all probability, it derives from the fact that few countries have engaged in such research and very few entomologists have had experience of the control of weeds by insects either by working on such problems or by seeing the results that have sometimes been attained. But apart from that, the answer, I think, lies in our textbooks of plant ecology, for they contain little or nothing to suggest a scientific basis for an entomological method of weed control. On the question of the significance of biotic factors in plant ecology, the textbooks refer to the effects of grazing by herbivores, to seed distribution by animals, and to the influences of human activities. But what importance do they attach to the vast army of insects that develop at the expense of the world's plants? There is barely a plant species but has its peculiar complex of insect enemies, specialized to attack it and its close relatives. Yet faced by this horde of plant enemies, the textbooks of plant ecology have little comment to make beyond some reference to the value of insects as pollinators. It is evident that, though these textbooks do not provide a scientific basis for the entomological method of weed control, what needs modification is not our belief in the method (for this has a good pragmatic basis) but the views of the textbooks on the importance of insects in plant ecology.

It is of course true that there is very little information available as to the effects of insects on plants in their native countries, and the extensive information on the damage caused to economic crops by insects is barely relevant to the question. These crops are growing under conditions in which plant competition is practically eliminated, and the assessment of the damage caused, while valuable from a commercial point of view, has no relation to the question of the "control" exercised over the plant by the insects concerned.

On the other hand, in dealing with plant communities and their development, the ecologist almost never attempts to isolate or measure the factor of insect infestation, and in consequence this factor is not accorded any significance in his account of the processes of plant ecology. There are exceptions to this general rule.

For example, Phillips (1931, 1935) in his study of the Knysna Forests in Cape Province concluded that insects "probably are wholly necessary for the keeping of a proper balance in the organic scale". However, he found no evidence that biotic agencies could change the nature of the climax, and concluded that, in this region, they were responsible, at most, for originating subseral succession.

Another plant ecologist, Bews (1920), made a study of the plant ecology of the coast belt of Natal. He found that regeneration in the open spaces of the forest is not always from seedlings of the surrounding dominant trees, for though these may produce abundant seed, this is commonly destroyed by insect enemies during the stationary climax period, so that none germinates. In consequence, some of the sub-dominant trees may show signs of gradually supplanting the dominant ones. Bews observes that the animal influence can thus prove more potent than the climatic in leading to changes in the climax phase.

Here we have two plant ecologists insisting on the importance of the part played by insects in plant communities, and I will now take briefly from two entomological workers evidence of the influence of insects on the density of weeds in their native habitats.

First, there is the investigation carried out by Cook (1942) into the reasons for the increase in cacti on the Great Central Plains of Utah. His observations led Cook to believe that very probably a common moth (*Melitara dentata*) had kept the cacti in check for years, but that the period of drought from 1930 to 1940 had adversely affected the insects, permitting in consequence a great increase in cacti. It was to be anticipated that subsequent heavier rainfall would greatly increase the insect population and redress the balance.

For the other illustration, I shall refer to my own observations (Wilson, 1943) on the effects of insects on St. John's wort in southern France. It was apparent that, on the whole, human activity favoured the weed by preventing the development of the dominant shrubs and trees that would otherwise have eventually replaced much of the St. John's wort. It was also evident that insect enemies greatly decreased the rate of growth of the St. John's wort and that this must seriously reduce its capacity to compete with grasses and other plants which are its normal competitors in the absence of the dominant trees and shrubs. Also, it was observed that the insects sometimes eliminated completely, or nearly so, quite large areas of the weed, making the land available for other plants. The conclusion, therefore, was reached that within limits set by soil, plant succession, and human activity, St. John's wort in that area was controlled by phytophagous insects.

These then are some of the few studies made in this enormous field of enquiry, but the positive conclusions already reached, allied to the catastrophic effects produced on the densities of some alien weeds by introduced insects, make it inevitable that increasing attention will be given to these problems. Already, in Australia, we have research workers engaged in studying quantitatively the effects of the introduced insects upon the density of St. John's wort, and the associated botanical changes as the weed diminishes. This is, of course, a special case of the host-plant-phytophagous-insect relationship, but it is to be expected that other workers will enter this little studied field and give attention to examples of the normal case of native host-plants and their native insect complexes.

When such detailed studies are made, it will be found, I think, that the phytophagous insect operates within a very complicated structure of population balance, in which the populations of the competing plants and their several associations of phytophagous insects, and parasites and hyperparasites of these insects, are mutually interactive; also, that the results of these interactions are affected by differences in weather and climate, soil, and other factors. Without attempting to follow here the intricacies of such complex interactions, I think we can point to the essential characteristic of these biological systems from the viewpoint of the entomological control of weeds. It is that the phytophagous insect reduces the rate of growth (in the broadest sense) of a host-plant which is in competition with other plants, and in so doing it reduces the host's capacity to compete with these competitors.

So when we introduce an insect to control an alien weed, it is not necessarily intended that the insect alone will greatly reduce the weed density, but, alternatively, that the insect will reduce sufficiently the host's power of competition to permit plant competitors to displace it. A very good illustration of this result of insect introduction is to be seen in the control in Fiji of *Clidemia hirta* by *Liothrips urichi* (Simmonds, 1934). There the introduced thrips checked the growth of the terminal shoots of *Clidemia*, and this reduction in growth allowed competing plants (some of which were useful fodder) to outgrow the weed, further reduce its vitality by overshadowing it, and finally, by smothering, virtually to eliminate it.

With alien weeds that are highly dominant (e.g. prickly pear) the part played by competing plants will be far less evident, and the reduction in the weed's density may be almost entirely attributable to mortality caused by the introduced insect, with other plants doing little more than colonize the soil made available by the death of the weed. But with any weed the degree of its dominance over its competitors varies from place to place according to differences in environmental conditions, so that an insect introduced to attack an alien weed will play a more prominant part in one place than in another where its beneficial effects are augmented by more vigorous plant competition.

Nevertheless, I believe it to be true that, if an otherwise suitable phytophagous insect finds the whole area occupied by the alien weed to be an environment suitable for its ready increase, and if this increase is not fettered by natural enemies but is free to progress within the limits of the food supply, then the insect alone is able to effect a substantial reduction of the host's prevalence, the extent of this reduction being largely dependent upon the facility with which the insect can discover isolated areas of the host-plant.

The next matter that I wish to discuss concerns the distributional characteristics of a weed and its associated monophagous insects, and the bearing of these characteristics on attempts to control alien weeds by insect introduction. I will discuss the matter in relation to St. John's wort, but I know that these same characteristics are found in some other weeds, and I believe them to be of general if not universal occurrence.

The climatic tolerance of St. John's wort is much greater than that of any of its associated insects. Each of these occurs within a comparatively narrow area, and the zone within which the insect is common is yet a fraction of that narrow area. The total area in which the weed occurs is made up of a mosaic of the overlapping areas of distribution of the insects. That is one characteristic.

The second consists of a marked tendency for the weed to be attacked by groups of very closely related species. For example, St. John's wort is attacked by at least six species of *Chrysolina,* four *Anaitis* species, three *Actinotia,* two *Agrilus,* two *Allantus,* two *Aristotelia,* and two species of *Perrisia.* These together form a good majority of all the monophagous enemies of *Hypericum perforatum,* and probably further search in the lesser known parts of the range of the weed would disclose other enemies belonging to these genera. The important aspect of the occurrence of such closely related insects is that they play the same role in relation to the host weed in different areas, and that the essential difference between them consists in their special adaptation to different climates.

It is evident that phytophagous insects are generally quite highly specialized as to climatic requirements, and that the zone in which an insect is abundant indicates clearly the climatic conditions that are favourable to it and under which it may be expected to flourish in a new country. This being so, it follows that the initial requirement, when undertaking the entomological control of a weed, is a clear definition of the climatic characteristics of the area infested by the alien weed and in which the insects must be established. Then it is necessary to demarcate within the geographical area where the weed is indigenous the homoclimes of the newly invaded areas. Investigation of the common insect enemies of the weed within the limits so defined will discover the species most suited to the new environment. In a general way, and to various degrees in different projects, account has been taken of the climatic factor in earlier investigations. I do not know, however, of any instance where climatic criteria have been rigorously applied, and I believe that to do so would be to help raise the entomological control of weeds from its past unduly empirical basis.

From these remarks, it is clear that the important insect enemies of a weed are different in different climatic zones, and that for countries differing appreciably in climate different insect species should be introduced for the control of the same weed. This does not imply, of course, that a phytophagous insect that proves highly effective in one country will not be useful in another country harbouring the same weed. It does imply, however, that an insect that proved valueless in the first country might prove effective in the second.

There is another aspect of insect infestation of St. John's wort in southern France, which may well have its parallels with other places and with other weeds. I refer to the fact that when the host-plant is heavily attacked by insects there is severe competition between them for survival, and that, in the ultimate stage where the weed is eliminated or nearly eliminated, only one or two species remain in appreciable numbers. The species surviving under these circumstances is *Agrilus hyperici,* accompanied sometimes by *Chrysolina gemellata.* But if the severe inter-specific competition that occurs between insects when the host-plant is severely affected by them locally, results always in the survival of one or two particular species that always prove dominant in such competition, then it is a matter of considerable importance. Investigations on the entomological control of weeds are very lengthy undertakings chiefly because the fear that the introduced insects will attack other plants necessitates exhaustive and time-consuming starvation tests. If many species are introduced into a country, the labour and time required are very considerable. If, therefore, by an improved process of selection it is possible to reduce the number of species to be imported and established to a very small number, the starvation test process can be shortened considerably. I think it possible that, basing an investigation initially on well-defined climatic criteria, and subsequently on the determination of the dominant species under conditions of severe control of the host, might prove to be scientifically sounder and far more expeditious than less calculated methods of achieving the same end.

The last question that I wish to discuss relates to the problem of establishing phytophagous insects. Our experience in Australia with *Hypericum* insects imported from England is interesting in this regard. Over a period of years we liberated repeatedly five English species—three species of *Chrysolina* and two of *Anaitis.* To varying degrees watch was kept upon the liberated insects, and it was found that the colonies persisted for some time but gradually dwindled and eventually disappeared. It was known that predators were preying on the insects, and the conclusion was reached that an unfavourable climate combined with predator attack made the establishment of these insects impossible. Such results as these led Currie and Fyfe (1938) to discuss the question of the need to liberate insects in large numbers when attempting to establish them. They came to the conclusion that usually the results of the first liberation show whether or not an insect can be established, and that the liberation of large numbers is unnecessary.

And then, in the following year, 1939, *Chrysolina hyperici,* which had been last liberated five years earlier, was found in large numbers at this last liberation site, and subsequently this insect increased to astronomical numbers. Since 1939, we have collected and redistributed *hyperici* to many new areas, and we have found that in order to get a new colony established it is desirable to liberate at one spot not less than several thousand beetles. Now that these beetles are easy to secure, we think in terms of hundreds of thousands for a liberation site.

I think this example of *Chrysolina hyperici* is very suggestive. It suggests, for example, that many insects that have been liberated without becoming established might still be established if liberated in sufficiently large numbers.

In its native habitat an insect may be rare or common but it is generally distributed within the limits of its total range. Consequently, dispersal occurs chiefly within the area already occupied. When an insect is colonized in a new country, on the other hand, there tend to be numerous isolated specimens at the periphery of the zone occupied which do not mate or reproduce. Further, numerous predators thin out the numbers of the liberated insects, thereby increasing the extent of individual isolation, and having a correspondingly adverse effect on the insect's rate of reproduction. Now these predators tend to be very polyphagous species (ants, birds, and the like) whose numbers are not closely linked to those of the introduced insect, and which consequently have, proportionally, a far greater adverse influence upon the introduced insect if it is rare than if it is numerous. Consequently, the greater the density of the insect at liberation, the less important will be the activities of these general predators. The density of the insects freed at the liberation site should be sufficient to allow for the loss caused by the isolation of dispersing insects and the mortality caused by predators and parasites, and yet leave enough insects to effect an overall increase in density in the subsequent generation.

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PROGRESS IN THE ENTOMOLOGICAL CONTROL OF ST. JOHN'S WORT IN AUSTRALIA

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OVER recent years, the prospects have consistently improved for the eventual attainment in Australia of a satisfactory level of control of *Hypericum perforatum* by means of introduced insects. At the time of the last Pacific Science Congress, whilst investigations were still being conducted energetically, they were supported more by determination than by the optimism which underlay the earlier work.

This earlier work had proved disappointing. Detailed studies had been made of the insect fauna associated with St. John's wort in England. Eight insect species had been investigated in detail, and others less thoroughly, and many of these had been sent to Australia, after being subjected to extensive starvation tests, and established there in quarantine. After additional tests had confirmed their restriction to St. John's wort as host, five of these insects (three species of *Chrysolina* and two species of *Anaitis*) had been liberated on many occasions in the field (Currie and Garthside, 1932).

The very considerable body of work that had been done at this stage appeared to have been completely without practical result. It was known that after liberation the insects suffered severely from native predators (ants, spiders, birds, and so on), and a check on the subsequent history of liberated colonies indicated that, though the insects persisted for some months or even longer, they eventually disappeared entirely. At last, the conclusion was forced upon us that climatic unsuitability allied to biotic resistance made the establishment of these insects very improbable. This seemed the more likely because examination of the literature concerned with insect establishment suggested that generally insects, if they could be established at all, became established readily after the liberation of comparatively small numbers. (Incidentally, this is not a view that we are now inclined to accept.)

As a result of this, we changed the centre for the European work on St. John's wort from England to southern France. Reference to climatic data showed that this area—which was also in other respects a convenient field of operations—had closer affinities than the areas already studied in England with the climate of the parts of Australia infested by this weed.

Research in this new area (Wilson, 1943) soon showed that St. John's wort there was attacked by a very different group of insects, and that several of these had a markedly adverse effect upon it. Of the five species considered to be major enemies of St. John's wort in southern France, the most important two species, after passing lengthy tests as to host restriction, were sent to Australia and liberated. These insects were *Chrysolina gemellata*, a leaf-eating species, of which a total of 5,400 were liberated in 1939, and *Agrilus hyperici*, a root borer, of which about 6,600 were liberated in 1939 and 1940.

At about this time also (November, 1939) *Chrysolina hyperici*, an English species which had been last liberated in 1934, reappeared in quite large numbers, and its population expanded rapidly in the following years.

Agrilus was consistently recovered in fair numbers in the years following its liberation, whilst *Chrysolina gemellata*, after disappearing for a while, reappeared in 1942, and has increased markedly ever since.

The earliest examples of the value of these insects were seen in 1942. By this time *C. hyperici* had increased considerably in the Bright district of Victoria, and several paddocks that had carried a heavy stand of St. John's wort for many years were practically entirely freed from it.

In *C. hyperici*, as in *C. gemellata*, there is a single generation a year and a high reproductive rate of several thousand eggs per female, oviposition taking place throughout the cooler half of the year. The larvae eat the procumbent foliage of the weed and give rise to adults in early summer. The adults tend to emerge at about the same time and for some weeks feed voraciously on the summer foliage and flowers of St. John's wort. During this period of adult feeding, which precedes several months of aestivation in the soil, the adults spend all their time on the aerial parts of the weed, and, such are the densities attained under Australian conditions, it is not uncommon to find up to two hundred or so beetles on each stem, the insects appearing like clusters of coloured berries.

The most obvious characteristic of infestation by these two Chrysomelid beetles at this time of the year is the occurrence of a "feeding front". The insects occur very densely on the weed over a depth of some yards and along a line commonly hundreds of yards in length. The beetles are eating steadily. Behind this advancing line, every leaf and flower of the weed has been consumed, and a comparatively thin beetle population wanders in an apparently random search for food. In the path of the advancing line, the weed looks green and fresh, though beetles may be present throughout it in moderate numbers. These lines of beetles may take the form of a gradually expanding circle, or of a more or less straight or curved line which passes gradually across an infested paddock.

It is quite common now for a dense, continuous, mass of St. John's wort, covering acres or tens of acres, to be converted in the course of the few weeks after adult emergence from a stand that is flourishing and green to one that is completely defoliated and brownish. This marked effect on the weed commonly takes place suddenly, but, of course, has been preceded by a gradual population increase. It is usual for defoliation to be caused to a limited but clearly delineated area in the first summer. In the following months, the population is enlarged very greatly by oviposition, and the larvae cause considerable damage to the procumbent foliage, damage which weakens the plants considerably and reduces the number of flowering stems sent up in the following spring. These larvae may cause complete defoliation, but it is usually with the transformation of these larvae into adults that the most startling results of attack become apparent. While it is probably quite common for complete defoliation to be attained after a stand has been infested for two years, the period required depends, of course, on the size of the area and of the initial insect population. I should say that the continuous presence of beetles in a single stand of the wort for three or four years, or even longer, is by no means uncommon.

The occurrence of the Chrysomelid adults in these dense feeding lines greatly facilitates their collection, for one can move along the line knocking the insects into some receptacle, and collecting them, literally, by the pailful. One of my colleagues, Mr. T. G. Campbell, with others, has collected some five millions in this way over the last few years, and by this means has begun colonies in most of the main *Hypericum* centres in Australia, apart from sending supplies overseas, both to New Zealand and to the United States.

Wherever these Chrysomelids have been established, there has been a marked effect upon the weed, complete defoliation occurring over a larger or smaller area. In general, too, it seems that the beetles deal quite satisfactorily with the problem of regrowth of the wort, which is a common feature of the process of control.

It was at Bright, the initial home of St. John's wort in Australia and one of the most heavily infested districts, that the Chrysomelids were first established, and it is here that we have longest experience of their effectiveness. I have no hesitation in saying that in the general neighbourhood of Bright the insects have caused a marked reduction in the total amount of St. John's wort, especially on the lower-lying and more valuable lands. This improvement in the problem has resulted, I understand, in a marked rise in land values in this district.

We do not see why the position should not continue for some time to improve in the Bright area, or why comparable results should not be attained in other *Hypericum* areas in Australia. We cannot, however, forecast the eventual general level of infestation to which the weed will be reduced by these insects, the time that will be taken for the beetles to bring the weed to this new level, or whether the degree of control eventually obtained will be deemed sufficient. All these things depend on a number of factors that have not yet been measured. In particular, we are not clear as to the insects' abilities in finding fresh areas of the weed when they bring about complete defoliation of any particular stand. It may be that such defoliation commonly results in a severe check to the insects' population.

However, these matters, for the moment, are guesswork. The position is best summarized by saying that while we are highly pleased with the results being attained in the field, we do not exclude the possibility that the introduction of other species may yet prove desirable. We are, in fact, considering now the question of introducing into Australia *Zeuxidiplosis giardi*, which forms leaf bud galls on St. John's wort.

So far, I have said very little about *Agrilus hyperici*. This insect, though established since its liberation in 1939 and 1940, does not seem to have attained any importance. It can be recovered at several places (we have sent Australian *Agrilus hyperici* for liberation in the United States) but does not seem to increase very rapidly, and, indeed, is in some danger of being eliminated through the severe control by the Chrysomelids of the St. John's wort stands in which the root-borer is established. This insect has failed to fulfil its earlier promise. Though without proof in the matter, I am inclined to attribute this to climatic factors, particularly to the adverse effect of rain during the oviposition period. This insect is suited to areas of warm temperature and summer drought, and in such areas I think it would be very effective.

Chrysolina gemellata has quite fulfilled the forecast made in 1943 (Wilson, 1943) that it would prove at least as valuable as *C. hyperici*, and would probably be more effective than *hyperici* in the warmer districts. The populations of the two beetles are now mixed almost everywhere and it would probably be very difficult to find a pure colony of either species. *C. gemellata* in these mixed colonies is now nearly always more numerous than *hyperici*, though five years ago *hyperici* was vastly more common than *gemellata*. Though the *hyperici* population has continually expanded since that time, *gemellata* increases so rapidly that it has become increasingly predominant.

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QUANTITATIVE STUDIES ON THE BIOLOGICAL CONTROL OF ST. JOHN'S WORT (KLAMATH WEED) IN CALIFORNIA[1]

By C. B. HUFFAKER, Division of Biological Control, University of California

THE gross progress of the effort to achieve biological control of the Klamath weed, *Hypericum perforatum L.*, in California by the use of the two introduced beetles, *Chrysomela* (*Chrysolina*) *gemellata* Rossi and *C. hyperici* Forst., is beyond the scope of this paper, which is to cover certain preliminary results from and quantitative methods used in these studies. Smith (1947) and Holloway (1948) reported the initiation and early progress of the programme in California, and expressed their indebtedness to various organizations and personages, particularly in Australia, for aid in this work. Thanks are again expressed to all concerned.

At the initiation of the beetle importation programme, it became desirable to devise and utilize methods of study calculated to record in detail the changes which might ensue in the plant populations of the infested ranges as a result of beetle action. The destruction of *Opuntia* in Australia by *Cactoblastis* has been so striking that no one could question this insects's effectiveness. However, results are not always so marked. Wilson (1943) pertinently stated in this connection, "The intended function of an introduced phytophagous insect is not necessarily to kill the weed by its own unaided efforts, but alternatively, so to reduce the power of competition of the host that it yields place to competing plants; and when a weed has not a considerable advantage in competition over its competitors, a relatively small amount of damage to it may satisfactorily serve this purpose". The methods used in this study, therefore, were predicated on the possibility that success, if any, might be accomplished in one or more indirect ways or in some partial measure.

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[1] The over-all project, of which this study is one phase, is under the co-ordinating supervision of J. K. Holloway, Entomologist with the U.S. Department of Agriculture and Associate in the Experiment Station of the University of California, and is a co-operative one under the direction of Harry S. Smith of the University of California and C. P. Clausen of the U.S.D.A. Bureau of Entomology and Plant Quarantine.

For the most part, the area of some 400,000 acres of Klamath weed and the non-Klamath weed annual-type ranges over the greater part of northern California have long since been depleted by overgrazing to a point where the native, perennial, climax grasslands have disappeared. A study of this kind, therefore, behoves one to ponder the degree of improvement which, with maximum effectiveness, could be expected. Clements and Shelford (1939: 285-293) considered that three-fourths of the land south of Mt. Shasta and from the Coast to the foothills of the Sierra Nevadas in northern California was originally climax or related grassland, and that the replacement by annuals was largely due to overgrazing. According to Hormay and Fausett (1942), annuals now make up 90 to 100 per cent of the forage on approximately 25,000,000 acres of foothill and valley ranges in California. Sampson (1944), Jones and Love (1945), and Bentley and Talbot (1948) have considered this question and have arrived at the conclusion that re-establishment of perennials would not be possible nor necessarily desirable everywhere in this region. The return of Klamath weed infested areas to a condition of vigorous annual-plant cover, if not to one of climax bunch grassland, would be a most welcome outcome to cattlemen in California and in the adjoining western states as well.

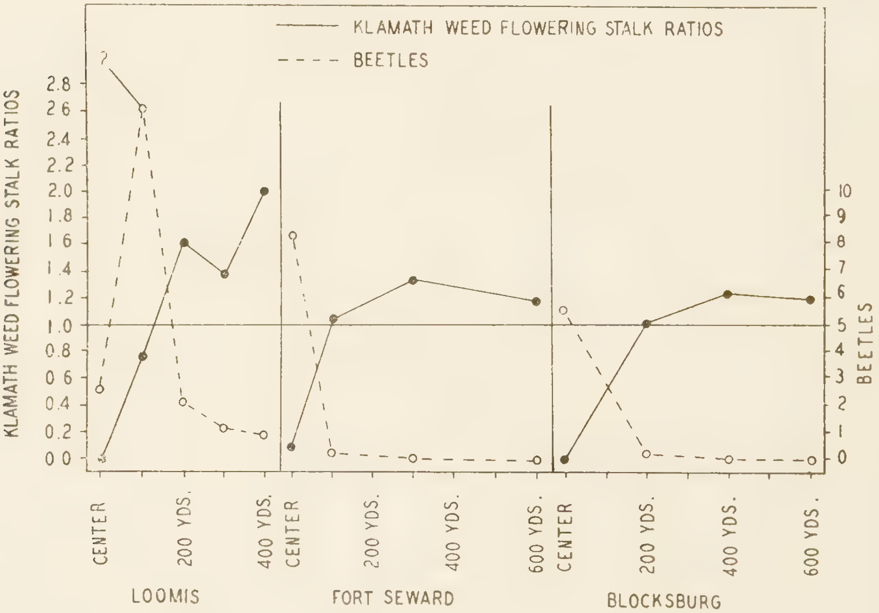

FIG. 1.—Klamath weed flowering stalks in 1948, as ratios based on records for 1947 taken as unity, and *Chrysomela* (*Chrysolina*) densities in 1948 at three locations in California. The flowering stalk ratios are averages from ¼ sq. metre quadrats, and the numbers of beetles are averages per 200 sq. cms. (After Huffaker and Holloway, 1949.)

Under present practices and conditions, there does not appear to be another weed equally or more objectionable in the California Klamath weed country which has the necessary characteristics for coming in where this weed may be removed. Hence, with the destruction of this plant, the predominant annual-plant cover characteristic of the region would likely regain the land except in the most favourable or most unfavourable situations, in which cases perennial bunch-grasses or inferior weedy species, respectively, would enter the picture.

A weed under biological control by its density-dependent, controlling insect would of course undergo the oscillations characteristic of this type of control. The success of this project will be ascertained not on the basis of the number of acres completely freed of the weed but in terms of the average level of weed abundance over a period of years as it is maintained in equilibrium with the insects feeding on it; as contrasted with its proved capabilities in the absence of the beetles. It is expected that if the programme is successful, the stands of weed will be greatly reduced in size and will constantly shift from place to place, as each in its turn is discovered and gradually weakened or destroyed. New weed patches will of course be coming into being all the while.

The level of this prospective equilibrium will be followed over a period of many years. In addition, insecticidal elimination of the beetles, as a check, will be used from time to time to learn if the weed will have retained its earlier aggressiveness under the perhaps changed conditions several years hence. If so, the weed should significantly reappear in check areas so treated.

As an adjunct to this programme, tests are being conducted in cooperation with the Agronomy Division of the University of California to ascertain if the action of the beetles will help to eliminate competition and thus aid in the establishment of seedlings in a programme of artificial range reseeding. It will be important to synchronize the time of seedings with the proper stage of intensity of beetle attack.

METHODS OF STUDY

Early in this work techniques and equipment were adapted with the purpose of establishing methods which could be used consistently throughout the study. Sampling methods were decided upon for use in following both beetle population changes and plant changes associated or not associated with the beetles' feeding. The prospective locations for the intensive studies were outlined. Methods for use in complementary, controlled experiments on the ecology of the weed and the specific destructive effects of the beetles were devised. Seeding experiments and the locations for the first studies along this line were planned and have been initiated at one location. The specific insecticides and methods for use in the aforementioned checks will be decided upon when the time arrives.

Size of Quadrat.—The quadrat size selected for this study was arrived at by the use of Cain's (1938) species-area curve technique. In 1946 preliminary quadrats of $\frac{1}{32}$, $\frac{1}{16}$, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$ and 1 square metre, respectively, were studied and all plant species present recorded. The data, after plotting in a species-area curve, showed that (1) an area of $\frac{1}{16}$ sq. metre sufficed for a poor development of annuals of about

7 inches stature, (2) ⅛ sq. metre was required for adequacy in a good development of annuals plus some perennials of 10 to 14 inches stature, and (3) ¼ sq. metre sufficed for any communities studied, including Klamath weed of 24 to 36 inches in height. One-fourth sq. metre was therefore selected as the quadrat size.

Sampling Frame.– It is believed that the sampling frame (figure 2) admirably fills the needs of this study. The excellent summary of Pechanec and Pickford (1937) covering the essentials of a desirable sampling method carried great weight in arriving at the features of this sampler. The ranges in the Klamath weed areas of California are, as previously stated, largely of the low annual-plant habit. Only a few bunchgrasses remain. Klamath weed is sometimes bunched, but is usually present as a dense stand, taller than the annuals. Methods which involve counting of the plants or stems were wholly impractical and unnecessary in this work. A point-list or line-transect method would probably have given satisfactory results, but it appeared advisable to establish definite, permanent quadrats of ample size for following the developments.

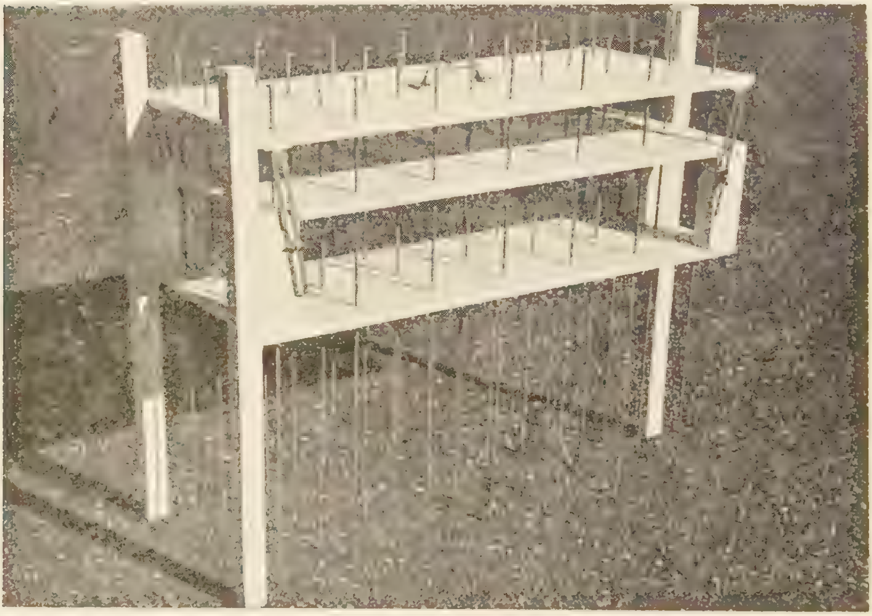

FIG. 2.—Range plant sampling frame. See text.

The frame used in this study combines the point-list and quadrat methods, by utilizing 28 brass rods as point indicators mounted in a wooden frame encompassing ¼ sq. metre as the quadrat area. The species of greatest development within a radius of 2½ cms. of each rod was recorded at each survey. The rods are numbered and slide up and down in the guide-holes as elevations or depressions in the terrain are encountered. The frame has three legs, enabling it to sit firmly on a rough area. The top board is adjustable to either a high or low position. It is lowered to the level of the middle board when in use in order to allow the rods maximum freedom of movement with the irregularities of the terrain. It is constructed of plywood and light enough for easy carrying.

Cylindrical Soil-Cutting Beetle Sampler.—A metal soil-cutting, cylindrical sampler was constructed for use in following the *Chrysomela* population changes. This type of sampler appears to be adequate for estimating the actual production of beetles each year on given ranges. The population has been and will continue to be sampled at the period just prior to active feeding of adults at the weed's flowering period. At this season, almost the entire population is in the soil, about ½ to 1 cm. beneath the surface. Some larvae and adults, however, are found above ground level but they are inactive at this time and readily taken with the sample. The sampler is a heavy metal cylinder with hand guards on the sides for gripping as the cylinder is twisted into the soil. It cuts circular soil samples 6 to 7 cms. deep and 200 sq. cms. in area. The beetles in the samples may be counted immediately in the field, or the samples taken into the laboratory in paper bags, cold-stored and the counts made as time permits.

Quadrat Lay-Out.—The plan for following field changes up to the present time (with other areas to be added later) includes three study localities, one at Loomis, in the Sierra foothill region, and two in the Coast Range at Fort Seward and Blocksburg, respectively. Beetles were released at the three places: 5,000 *C. gemellata* at Blocksburg in February, 1946; 1,800 of the same species at Loomis in January and February, 1946; and 1,300 *C. hyperici* at Fort Seward in July, 1946.

As stated by Huffaker and Holloway (1949), "Quadrats were laid out at the central zone (of release) and at several other zones at various stated distances from the centres; the quadrats of a given zone placed 6 yards apart along a wide 'arc' described roughly by the 100-yard, 200-yard, etc. radii." The general directions from the release centres were determined by the nature of the range, as often a particular range was surrounded on two or more sides by forested or cultivated land. The counts of flowering stalks were taken in quadrats laid out in the same manner, but a greater number of quadrats were used in this case at each distance. By using the counts of flowering stalks of Klamath weed, a greater number of replicates could be used and such data are a sensitive measure of the relative density of Klamath weed from year to year and place to place, and complement the inclusive and intensive analysis of the total vegetation of a smaller number of quadrats.

Seed Production Plots.—Small plots were laid out prior to the establishment of effective beetle colonies. The purpose was to learn the degree to which partial foliage destruction (simulated beetle feeding) would curtail seed production. The dried weights of the foliage clipped to effect ½ reduction and ⅞ reduction of foliage, compared to the check, were recorded and the seeds produced from each quadrat estimated. Five replicate quadrats were established for each condition. The plants were clipped once on April 23, and the seed production counts were made from material collected on July 30, 1947. The number of upright stalks produced in each quadrat was counted in the field. Three stalks from each quadrat were taken into the laboratory. The total number of pods was counted for each of these stalks, and the seeds in two pods of each stalk were counted, the results being expressed in terms of the number of seeds per quadrat of ¼ sq. metre.

After exposure of samples of the seeds to light and to alternate, moist germinating conditions and to drying, the total percentage germination was ascertained for the seeds of each quadrat.

Root Production Tests.—Similarly, tests were conducted to learn the degree to which partial foliage destruction (simulated beetle feeding) would curtail Klamath weed root production and influence survival through the dry California summer. Fifteen 30-gallon drums were filled with soil, embedded nearly to the top rims in an experimental field, and three seedlings of Klamath weed transplanted into each drum on March 14, 1947. All plants became established and grew. Clipping was started the first season, but was discontinued at the end of the normal beetle feeding period (June). During this first summer the plants received adequate irrigation and by November all plants had reached equal, vigorous development, filling the drums. Clipping was reinitiated on November 3rd and continued through June 3rd, 1948, encompassing the period of normal beetle activity. During this second dry season (1948) no irrigation water was supplied. The drums were deep in the ground and had been well supplied with holes to allow capillary movement of water from the soil beneath into the soil inside the drums. Drums had to be used in order to make it possible to remove the soil from, isolate, and dry-weight the roots produced. The plants were foliage-clipped to effect ½ reduction in five drums, and ⅞ reduction in five drums, as compared to the five check drums.

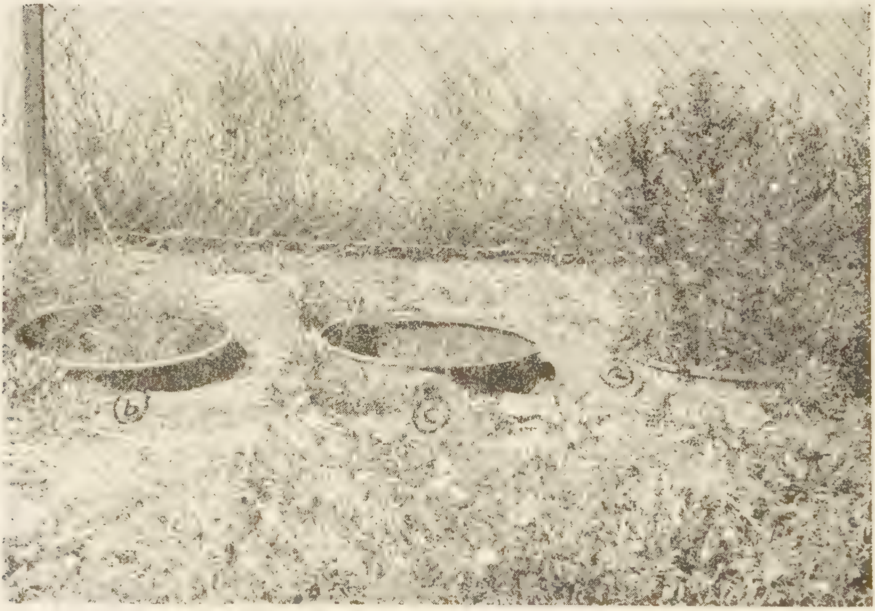

FIG. 3.—*Hypericum perforatum* grown in 30-gallon drums and foliage-clipped to effect (b), ½ foliage destruction; and (c), ⅞ foliage destruction compared with the check, (a). The degrees of clipping through June 3, 1948, approximated ½ and ⅞, respectively. However, the vigour of the check plants is demonstrated by the extent to which they outgrew the clipped plants, the subsequent top-growth of which was curtailed.

The relative effects of the clipping can be seen in figure 3. The dead plants and the maximum lengths and weights of the root systems were recorded for each condition.

PRELIMINARY RESULTS

Direct Effects of Beetles.—The obvious and direct damage to the weeds by the insects can easily be observed. The larvae feed actively at warm periods throughout the winter and early spring on the prostrate, leafy winter growth. By midwinter and early spring when the larvae reach near-maturity, the destruction may be very intense if sufficient time has elapsed for the building up of a large population. At every suitable location, complete destruction of plants has been observed. A large proportion of those plants which are fed upon heavily by the larvae and continuously stripped of foliage from mid-winter to spring fail to put out growth and soon die. Some of the most vigorous of these plants as well as those which are fed upon to a less degree may send out shoots and these, as well as plants distad of the centre of heavy population which have escaped larval feeding, may be destroyed or weakened by the feeding of the adults. Adult activity reaches its greatest conspicuousness synchronous with the weed's flowering period in late spring.

The critical action of these insects is the intense feeding of the maturing larvae, which keeps the plants continuously defoliated over a long period at a time when the limited food reserves in the root system have reached a low ebb. Mass destruction of plants from this action alone has been observed, whereas adult feeding, voracious as it is, is extended over too short a period of time to effect wholesale death of the plants in the absence of the previous action of the larvae. The action of the larvae was so intense at Loomis (figure 1) that nearly all died in the central area due to the fact that defoliation was so complete that very few of the larvae present in January were able to mature. At that time, half-mature and nearly-mature larvae were seen moving over the ground in great numbers, later dying for lack of food.

In this area where the plants were defoliated too soon by such a heavy population, scattered weeds were able to send up flowering stalks which were unmolested later due to the relative absence of mature beetles. Next year, these isolated plants will undoubtedly be attacked. True, the action of the adults supplements that of the larvae by outright destruction of weakened plants which would otherwise survive the larval feeding, and by curtailment of seed production and root development, and by decreased general competitive vigour of plants which may or may not have undergone significant larval feeding along the margin of heavy activity.

The production of beetles at the 100-yard zone at the Loomis location is perhaps half that necessary for the removal of Klamath weed. The data of figure 1 may be used in this connection. The number of approximately mature beetles produced at the several central zones was undoubtedly less than the number which actually produced the observed effects. Many had died from intra-specific competition prior to the sampling. At the 100-yard zone at Loomis, however, the loss of the beetle population was at a minimum from this cause, the reduction in flowering stalks was only about half (compared to the figures for the 200-, 300- and 400-zones), and the figure of 13 beetles per sample may be taken as an indication of the average production from an area which is under moderate beetle pressure. Laboratory tests with potted plants have shown that from 15 to 25 larvae can completely defoliate an area of about 200 sq. cms. heavily covered with basal growth. The production of 13 beetles per sample would be about

2½ millions per acre. The collection of more exacting data along this line is contemplated.

Range Plant Population Changes.—The changes in range plant population structure associated with beetle feeding at these three study areas previously have been reported by Huffaker and Holloway (1949). Their figure 1 is repeated as figure 1 in this paper. The "question mark" indicates that the destructive population was certainly greater than the population recorded at the time of the sampling, which is the figure shown at the central zone for the Loomis location. Their conclusions are herein quoted or otherwise summarized:

"The data of figure 1 emphasize the completeness with which Klamath weed was removed by beetle action from the central areas at the three locations, and show, by contrast, the heavy weed stands still present surrounding these centres.

"The plant species which have thus far come in at the removal of the weed are largely those which were present as an inferior stratum or as less important associates in the Klamath weed community. Granting a longer period of continued beetle pressure under reasonable grazing management the areas may well pass permanently into higher levels of forage production, with the natural appearance of or seeding by more desirable range species."

Desirable plants which have increased due to the removal of the weed at one or more locations included soft chess, *Bromus hordeaceus, Festuca megalura, F. myuros, Erodium* spp. (considered obnoxious in Australia and New Zealand), *Trifolium* spp., *Lotus* spp., and *Danthonia californica,* the only perennial of the group.

Artificial Defoliation Tests.—Loss of vigour by the weed resulting from artificial defoliation (simulated beetle injury) included drastic reductions in seed and root production, as well as outright death of the plants due to reduced ability to withstand the dry season. Also, top growth recovery was very poor following foliage curtailment from November through May, the period of beetle activity (see Fig. 3).

Seed production records under different degrees of defoliation are shown in Table 1. Figure 3, though a picture of the root production

TABLE 1

Seed production estimates under different degrees of artificial defoliation in Klamath weed products at Auburn, California

Treatment	Quadrat	Number of Seed-Stalks	Number of Pods	Number of Seeds	Percentage Viable Seeds	Number of Viable Seeds
check	1	21	2,331	174,825	90	157,342
	4	12	2,196	92,232	55	50,727
	7	30	3,900	273,000	85	232,050
	10	17	2,023	109,242	85	92,856
	13	20	2,740	134,260	85	114,121
	Mean	20	2,638	156,711	80	125,369
foliage ½ clipped	2	10	780	36,660	65	23,829
	5	10	610	22,570	50	11,285
	8	11	297	13,959	65	9,073
	11	14	2,254	81,144	70	56,801
	14	7	189	10,584	75	7,938
	Mean	10	826	32,983	65	21,439
foliage ⅞ clipped	3	9	378	11,718	60	7,031
	6	7	364	13,468	70	9,428
	9	7	406	12,586	80	10,068
	12	11	484	16,940	100	16,940
	15	6	192	6,720	45	3,024
	Mean	8	364	12,286	71	8,723

tests, gives a relative impression of the degrees of artificial defoliation in these tests. The percentage germination of seeds was not notably different under the several conditions, but the mean number of viable seeds produced in the severely-clipped quadrats was only 8,723 compared to 125,369 for the check quadrats—only one-fourteenth as high. The reduction was also very pronounced in the moderately-clipped quadrats. Although only a single clipping was made and defoliation was not nearly as heavy or continuous as that occurring under moderate beetle activity, the seed crop was greatly reduced. Klamath weed tends to produce viable seeds under adversity though the quantity may be greatly decreased.

Cashmore and Campbell (1946) pointed out the importance of the reduction of seeds in the control of this weed. From these figures, the seed crop is seen to be tremendous. Somewhere along the margin of beetle advance from an initial colony establishment, adults moving outward from the centre which has been killed or defoliated by the larvae, would effect just such a destruction of the seed crop during a given year. This would help to prevent a quick reseeding two or three years later, after the beetles had declined.

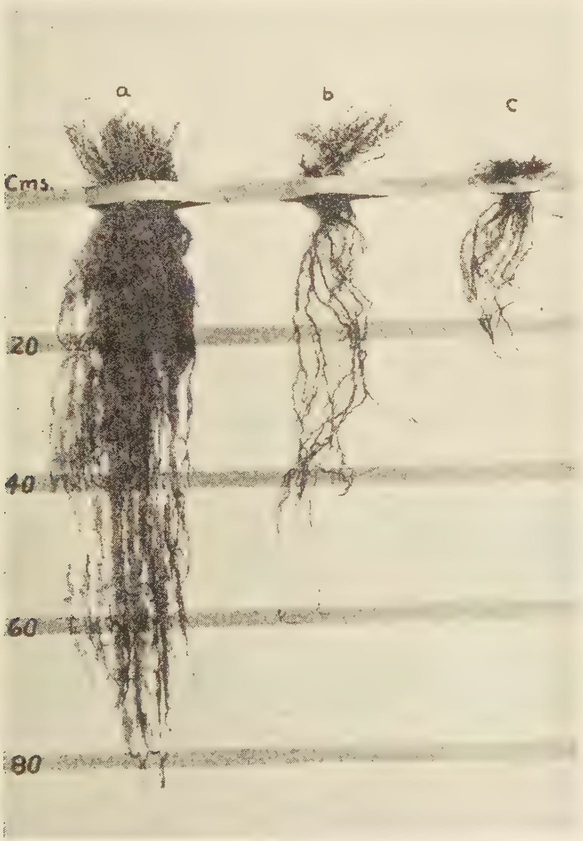

FIG. 4.—Roots produced by (a), an unclipped plant; (b), a plant moderately clipped; and (c), severely clipped from November through May. Depths of the root systems are shown in cms. Note the great development of fine roots on the check plants.

The root production results are presented in Table 2, and typical root systems under these conditions are shown in figure 4. Several points are of some ecological significance. Survival was not greatly influenced by moderate clipping; such plants were able to maintain comparatively long root systems, though their dry root weights were much more strikingly reduced. Mean survival was 93 per cent for the checks, 60 per cent for the moderately-clipped group and only 13 per cent for the severely-clipped plants. Average root lengths were 74 cms. for the checks, 61 cms. for the moderately-clipped plants (a slight reduction), and 34 cms. for the severely-clipped group. However, the mean dry weight of roots of the moderately-clipped group was only 29 gms., compared to 80 gms. for the checks. The roots of the severely-clipped plants averaged only 10 grams.

The vigour of the living, moderately-clipped plants was markedly affected though their long root systems had enabled them to survive. The dry weights shown in Table 2 give a good picture of the entire experiment in this respect, whereas figure 4 reveals the nature of the differences. It can be seen from this figure that the unclipped plants had very heavy, matted rootlets which permeated the whole container, whereas the main root branches of the clipped plants were relatively bare. On the range, similar root development differences surely occur, but the general pattern of weed destruction in heavy beetle centres is more rapid and severe than that which resulted from the severe clipping. Surviving plants in such centres undoubtedly suffer weakened conditions similar to those here described and their competitive advantage over other range plants would be reduced if not largely nullified. The action of these beetles has not thus far proven as indirect or partial as was anticipated, and actual destruction by beetles the following year would likely follow at most points where the action had reached a level of reduced vigour during a given year. The loss of a large part of the seed crop one year earlier would be of some significance.

TABLE 2

Root production and plant survival under different degrees of artificial defoliation of experimentally grown Klamath weeds.[1]

Condition	Replicates	1	2	3	4	5	Mean
check plants	percentage survival	67	100	100	100	100	93
	mean maximum root depth[2] in cms.	72	73	75	73	79	74
	total dry weight in grams	44	80	121	76	79	80
moderately clipped plants	percentage survival	0	100	100	33	67	60
	mean maximum root depth[2] in cms.	43	73	58	67	66	61
	total dry weight in grams	22	51	23	27	22	29
severely clipped plants	percentage survival	0	33	0	0	33	13
	mean maximum root depth[2] in cms.	18	33	37	20	62	34
	total dry weight in grams	7	12	10	9	12	10

[1] Three plants per 300 gallon drum embedded in field at Albany. See text.
[2] Based on maximum depth of each of three plants.

SUMMARY

Quantitative sampling methods and experimental procedures in use for following the effort to achieve biological control of Klamath weed, *Hypericum perforatum* L., in California by use of the introduced beetles, *Chrysomela (Chrysolina) gemellata* Rossi and *C. hyperici*

Forst. are outlined, and rather striking preliminary changes resulting from beetle action are described. Other data on the ecology of the weed as an influencing factor are included. Projected or under way are studies on the over-all range plant population structure, oscillations in both weed and beetle densities, direct effects on the weed, indirect or partial effects on the general vigour, and on seed and root production, and synchronization of a seeding programme with beetle action.

Beetles have almost removed the weed from the central zones at three locations whereas the weed remained as a dense stand surrounding the release centres. Some desirable range plants have increased at these locations. It is expected that the cleared areas will be greatly enlarged next year.

Defoliation similar to moderate action by the beetles was shown to curtail greatly the seed production, to decrease root production, lower vigour and cause death during the dry season.

Larval feeding is the critical action of these insects, since defoliation by this stage is continuous over a sufficiently prolonged period of time to produce mass destruction of the plants.

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DISCUSSION

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LEGISLATION AND QUARANTINE

INSECT QUARANTINES WITHIN THE PACIFIC

By C. E. Pemberton, Hawaiian Sugar Planters' Association, Hawaii

With the progress of civilization all inhabited parts of the earth are being brought closer and closer together in point of time owing to the constant improvement in facilities for transportation. This is having a tremendous effect on the distribution of many species of insects, some of which have already become truly cosmopolitan. The spread of living insects, accompanying migrating peoples prior to the first invention of sailing vessels, rowing galleys fitted with sails such as used by the Egyptians about 3,000 B.C. or large sailing canoes used by Pacific island natives hundreds of years ago, was undoubtedly slight. As boats capable of long voyages came into use a potent means of insect dispersal was at hand. With the increasing use of ocean-going vessels in the fifteenth century, man and his goods began a new era in the movement of insects from one part of the world to another. Following the advent of Captain James Cook in the Pacific in the 18th century, whalers and traders sailed this ocean in quantity by 1840, carrying with them with probably little concern, water barrels inhabited by mosquito larvae, roaches of many species, domestic animals bearing ecto- and endo-parasites, and foodstuffs and other goods infested with insects of various sorts. Many of these insects unquestionably became established in regions where they were previously unknown.

With the decline of sailing vessels and the development of steamers, the transport of insects great distances in a living condition was greatly accelerated. During the latter half of the 19th century, steamers were coursing the oceans in all directions. The first steamer to reach Hawaii came from California in 1852 and the first one from Australia arrived in 1870. By the close of the century thousands of ships capable of carrying great tonnage of freight and ever increasing numbers of human passengers daily unloaded their cargoes at the many ports of the world. With this freight often came insects from widely separated points. By then many insect pests, imported from distant countries were taking a toll in food crops, affecting human and animal health and causing economic losses in other ways in countries newly invaded.

The twentieth century is nearly half over. It has been characterized by an ever increasing improvement in the machinery of transportation, culminating in the utilization of the airplane on a scale far beyond the dreams of enlightened men only a few decades ago. As with surface ships, living insects are being unavoidably carried alive great distances in airplanes, at speeds far exceeding that of sailing vessels and steamers.

Accurate estimates of the number of established immigrant insects in various countries are not available. The number must be very large. The extent to which insects have been moved from their native habitats and established in new regions is suggested by an examination of the present insect fauna of the Hawaiian Islands where intensive study in such a small country has covered the majority of the species. Of a total insect fauna of about 5,000 known species, as computed by E. C. Zimmerman in his "Insects of Hawaii", over 1,300 are foreign. A small percentage of these were purposely introduced. This is impressive evidence demonstrating the degree to which insects are accompanying modern man in his restless urge to migrate, travel and exchange the commodities of civilization. This applies not only to oceans but also to continents where geographical barriers once held the majority of the insects to restricted ranges. In comparatively recent times, railroads, automobiles and airplanes have broken down such barriers. It was as late as 1869 that the first trans-continental train crossed the mainland of the United States.

The establishment of general quarantines against the movement of injurious insects from one country to another came in very modern times and after large numbers of destructive species had already become widely dispersed and firmly intrenched in regions foreign to their nativity. Also of great significance is the established fact that these insects often proved more devastating in the newly occupied countries than in their native homes. The United States was recognized as a highly progressive nation by the beginning of the 20th century, yet it was not until 1912 that national legislation was adopted by the Congress establishing general plant quarantine for the nation. Many changes and additions to the quarantine laws have been made since then.

With the coming of trans-oceanic airplanes, insect quarantines in countries within and bordering the Pacific have become increasingly necessary and staffs to enforce them have grown. The menace of the airplane as a new vector of dangerous insects is a real one. From a small beginning in 1936, passenger planes and other aircraft loaded with freight of many sorts are now daily winging the wide expanses of the ocean in large numbers. Such traffic is permanent and will continue to grow. As an indication of the expansion of overseas air service, seven commercial airlines are at present operating in and out of Hawaii from various parts of the Pacific, whereas in 1936 there was but one. During 1948 an average of 40,000 trans-oceanic passengers arrived or departed at the Honolulu Airport monthly. In an effort to enforce the plant quarantine regulations, the Federal Government now maintains over thirty inspectors to handle this traffic in Hawaii. This service is operated on a 24-hour basis. Apart from this, there is a very large and constant movement of military aircraft between Hawaii, other Pacific islands and the mainland of the United States. These pose another problem in the efficient conduction of the quarantine work. In co-operation with the military services, the Federal inspectors meet and inspect these planes also.

Prior to the war, entomologists privately employed by the Hawaiian Sugar Planters' Association were stationed on Canton Island and Midway Islands for the sole purpose of inspecting, spraying and otherwise intercepting all insects occurring on Pan American Airways planes stopping at those places en route to Hawaii. This work started in November, 1936, and continued until December 7, 1941. The operation of such a quarantine proved highly effective because no plane reached Hawaii from the south or west without being screened through one or the other of these stations. The record of these inspections during the above period is of interest. The number of planes passing through these points was not large, there being only 301 during the entire period. However, of the thousands of insects removed from the planes, a total of 1,839 was found alive.

During the war the mass movement of military aircraft and surface ships over the Pacific and the urgency to conduct a conflict of colossal magnitude at the greatest possible speed, made it impossible to enforce efficiently and consistently any quarantine measure designed to prevent the carriage of insects in such craft. Much was done; but not enough and insects became established in new areas at an unprecedented rate. The experience in Hawaii gives ample proof of this. Entomological surveys beginning a year before the close of the war and continuing to the present day have revealed the presence and establishment of 43 species of insects new to Hawaii. Seventeen of these were first found in the vicinity of large airports on the Island of Oahu. Some have already proved to be serious pests in the Territory, some are beneficial and some appear to be neutral in their effect upon the fauna or flora of the Islands. Of the total, 14 came from the mainland of the United States, 19 were undoubtedly invaders from various Pacific Islands where they have been known, which includes New Guinea, the Philippines, Samoa, Fiji, Guam, Saipan and possibly some of the other Micronesian Islands, while the remaining nine are of undetermined origin.

Other lands of the Pacific have possibly had a similar experience though on a lesser scale. Where insect faunas were previously studied with care and where surveys have been conducted recently, considerabl information has accumulated to show that new immigrant insects have appeared in very recent times. A short survey of the insect fauna of Johnston Island in December, 1947, revealed nearly twice as many insect species established than had been recorded prior to the war. A careful survey of the insects of Guam was made by Dr. O. H. Swezey in 1936. Collections on that island during 1947 have brought to light many species not previously recorded, some of which are undoubtedly recent immigrants. The airplane would appear to be definitely implicated in the recent establishment of the migratory locust *Locusta migratoria*, phase *danica*, at Majuro Island in the Marshall group. During an insect survey on this island in 1936, Dr. H. K. Townes found this grasshopper well established on the island but only present at the airfield. The shocking effect upon fruit production in the Hawaiian Islands following the sudden appearance of the fruit fly *Dacus dorsalis* Hendel in May, 1946, is a striking example of the failure of quarantine measures to prevent effectively the transport of insects accompanying the mass movement of man and the materials conveyed by him.

Further evidence involving the airplane as a vector of living insects within the Pacific is suggested by the appearance in Honolulu in June, 1948, of the palm moth *Agonoxena argaula* Meyr. Conspicuous damage to coconut trees resulted. The moth at first occupied a fairly restricted area, suggesting that the introduction was recent. Since this moth is well known in Samoa, it is assumed that it came from there in planes which have been operating between Samoa and Hawaii during and since the war.

Efforts to prevent the carriage of insects over the Pacific in surface ships and aircraft, or to intercept them at ports of entry, are increasing. The need for such control is fully recognized and admitted. The intensity to which such service is being developed in Hawaii is discussed by Dr. C. L. Ritchie at the present Congress. The relation this inspectional work has to agricultural and horticultural industries on the mainland of the United States and particularly the State of California is also a large one. The recent establishment at Guam of an office of the U.S. Bureau of Entomology and Plant Quarantine to co-operate with the U.S. Navy in the development and enforcement of plant quarantine regulations at Guam and within the Trust Territory of Micronesia, is an important advance towards the protection of the many island units of that vast region against the invasion of serious insect pests. The maintenance of this station also offers additional security to Hawaii and the mainland of the United States against the eastward movement of insect species which are actually or potentially dangerous.

The most effective insect quarantines are those concerned with the movement of host materials. These relate to manifested freight and passengers' baggage and can usually be enforced with fair precision. Insects carried with their natural foods, be it living plants or parts thereof, or other substances, can generally be detected and intercepted through the enforcement of pertinent quarantine regulations. Insects travelling as hidden stowaways, entering or leaving airplanes at their various ports of call, present a quarantine problem which is yet to be solved satisfactorily. Much progress has been made in the development and application of insecticides for use within airplanes prior to and during flight. Over certain airlines such treatment has become obligatory. However, the potency of the various spray formulae used must be necessarily limited by the extent to which they affect human passengers and there is room for much improvement in methods and poisons used to meet this objection.

The presence of ornamental plants and other vegetation at and near airports serve to build up populations of phytophagus insects and increase their chances of gaining entrance to planes calling at such ports. This also facilitates the establishment of species leaving the planes. There is need for international agreement relative to the maintenance of plant free airports serving overseas air traffic. There should also be co-operative understandings respecting the sanitation of such ports with particular relation to breeding conditions for mosquitoes and flies. Further agreement is desirable with regard to the servicing of departing planes to eliminate insect contamination as far as possible. Such covenants are particularly indicated between countries occupying tropical or semi-tropical regions where insect life is active at all times.

THE PHILIPPINES' PLANT QUARANTINE AND INSPECTION SERVICE

By Gonzalo Merino,[1] Bureau of Plant Industry, Manila, Philippines

Several plant pests and diseases had gained entry into the Philippines during the years when it was not fully realized that something must be done to at least minimize the accidental entry of exotic plant pests and diseases through proper inspection, treatment, etc., of plants and plant materials entering our shores.

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[1] Charter Member of the National Research Council of the Philippines.

The first and most glaring example of the introduced diseases that caused incalculable damage is the coffee rust, *Hemileia vastatrix*. This is said to have entered the Philippines in 1885. Before that year, the Philippines had a profitable Arabian coffee industry all over the Philippines, particularly in Batangas where the best coffee groves were found in the vicinity of Lipa. Before that year, Lipa was a most prosperous town. The coffee barons reaped yearly harvests that were exported to Spain and elsewhere. Then came the coffee rust and that was the beginning of the end. The fine coffee plantations were wiped out and since then the Arabian coffee has not yet been replaced with better quality varieties.

The second example was the accidental introduction of the water lily, *Eichornia crassipes*, about the year 1912 or 1913, which has spread all over Luzon, Visayas, and Mindanao, creating problems on navigation in inland waters, on lumbering and on agriculture and even sanitation in this country. This weed now covers many inland streams and lakes at certain seasons of the year in some places, and throughout the year in other regions. This floating weed has been observed to harbour rats and mice during floods from the upper sections of the country to the plains. The rodents thus brought down invaded the rice fields and other farms, causing heavy damage on the crops. The weed itself crowds and chokes the rice plants, thus causing enormous losses to agriculture and industry.

The smuggling of the obnoxious weed (*Mimosa invisa*) by some people who used it to enrich the soil and to rotate with tobacco had unfortunate complications. For the weed has made extensive farm lands inaccessible to men and animals in the province of Isabela in Luzon, and in the province of Zamboanga and Basilan City in Mindanao, because of their long and thick spines which prick the flesh of man and animal alike.

The bunchy-top and wilt diseases of bananas and related plants introduced into this country through the promiscuous importations of varieties of bananas from other tropical countries in the early days of the Bureau of Agriculture, resulted in enormous losses to our abaca industry in Cavite, Laguna and Tayabas, as well as to our banana industry in these and in certain other provinces.

Other pests that certainly have been introduced are some of the scale insects which are noxious to fruit trees and other plants. Among these are the Florida red scale, certain oyster shell scales, and white flies.

A recent introduction is the African Giant Snail (*Achatina fulica*) brought for food by the Japanese army during the occupation which has been working havoc to garden and ornamental crops as well as to orchards in Manila and some towns in the provinces of Bulacan, Rizal, Cavite, Camarines Sur, Nueva Ecija, Nueva Vizcaya, Batangas and Laguna in the island of Luzon.

PLANT QUARANTINE LAWS

The first plant quarantine Act (Act No. 2145) was passed by the Philippine Legislature on February 5, 1912. But it was not made operative until the last quarter of 1914 when the Governor-General of the Philippines was requested by Dr. C. L. Marlatt, Chairman of the

U.S. Federal Horticultural Board, to require that nursery stock to be exported to the United States under permit must be inspected and certified by duly qualified and appointed plant quarantine inspectors.

Subsequently, the Governor-General issued Executive Order No. 88 in October, 1914, instructing the Director of Agriculture to prescribe rules and regulations for the inspection and certification of plant materials leaving the country for the United States.

Early in 1915, Act No. 2515 was promulgated to prevent the exportation from and the importation into the Philippines of infested or infected plants and to provide for the treatment and control of such pests and diseases already in or existing in this country.

To make the law operate more effectively, Act No. 3027 repealing Act No. 2515, was passed by the Fifth Philippine Legislature in March, 1922. This law requires the co-operation of the Chiefs of the Bureau of Customs, Pests and Constabulary and of the Municipal and Provincial Officials in the enforcement of the law. It provides for the creation of a Plant Quarantine Board, who shall serve without any additional compensation but shall be allowed the necessary travelling expenses in the performance of their duties. The members of the Plant Quarantine Board are as follows:

The Director of Plant Industry—Chairman.

The Director of Forestry—Member.

The Director, Institute of Science—Member.

The Dean, College of Agriculture, University of the Philippines, Los Baños—Member.

The Chief, Plant Pest and Disease Control Division, Bureau of Plant Industry—Member.

The Plant Quarantine Board is to deliberate and recommend measures to carry out the provisions of the law. Act No. 3027 increased not only the operating fund from 3000 pesetas to 6000 pesetas, but also the penalty, the prison term limit of 30 days raised to 6 months or a fine of 1000 pesetas or both the imprisonment and fine.

In 1930, Act No. 3767 regulating the importation of small animals was enacted. This law prohibits the entrance into the Philippines of living animals not falling within the scope of the term "Domestic Animals", the latter being under the Bureau of Animal Industry. Anyone desiring to import into the Philippines any living animal, insect (in any stage), birds, bats, reptiles, crustaceans, mollusks, mammals, or any other animal not within the scope of term "domestic animals", must file an application at least one month in advance on a form provided by the Bureau of Plant Industry. In the absence of such permit, the Director of Plant Industry shall have the imported animals held for observation and study as to whether or not their importation is to be allowed. If this importation is believed detrimental to the agricultural, interest of the country, the animals in question shall be disposed of or returned to the country of origin at the expense of the importer.

Philippine Ports of Entry

Presently, there are eleven ports of entry in the Philippines, namely: Manila, Iloilo, Cebu, Davao, Zamboanga, Jolo, Legaspi of Albay, Pañganiban of Camarines Norte, Aparri of Cagayan, Tacloban of Leyte and San Fernando of La Union.

The bulk of the inspection work is done in Manila, where most of the foreign boats dock and where the international airplane terminal is located. The ports of Cebu, Iloilo and Davao, are of minor importance as there are fewer boats with plant materials arriving there.

At the beginning of the quarantine service, the inspection of incoming and outgoing plant materials and their treatment was done in Manila only. Later on, as facilities of inspection rooms and fumigatoriums were made available, this service was extended to Cebu, Iloilo, Zamboanga and Davao. In the rest of the ports, the entrance of bulky plant materials, especially those that need fumigation and disinfection, is not allowed.

Regulations Under Plant Quarantine Act 3027

Rules and regulations promulgated under this act are issued in the forms of Administrative Orders by the Director of the Bureau of Plant Industry approved by the Secretary of Agriculture and Natural Resources and at times, especially those which involve internal matters, concurred in by the Secretary of the Interior.

Among the Administrative orders promulgated by the Director of Plant Industry to prevent the entry of pests and diseases of foreign origin are the following:

1. Administrative Order No. 2 (revised) governing the importation and exportation of plants and plant materials.

2. Administrative Order No. 3, prohibiting and regulating the importation of planting materials of the genus *Musa,* coconut, sugarcane, rice, pineapple, bamboo, tobacco, maguey, sisal and citrus of the Chinese yellow and red kid varieties. This order also prohibits the use of bamboo leaves, rice chaff and straw for packing and binding of merchandise and personal belongings, which are intended for the Philippines.

3. Administrative Order No. 5, series 1946, regulating the importation of coffee plants and beans because of the coffee berry borer *Stephanoderes hampei,* and other pests and diseases of coffee.

4. Administrative Order No. 8, prohibiting the importation of fruits from the State of Texas and Mexico, because of the Morelos orange worm or Mexican fruit fly (*Anastrepha ludens*).

5. Administrative Order No. 9, prohibiting the importation of certain fruits and vegetables from the Mediterranean fruit fly infested areas.

6. Administrative Order No. 7, governing the importation of living animals as provided by Act 3767.

Under Act 3027 are also promulgated and enforced Administrative Orders which regulate the control and eradication of native or introduced pests and diseases, among them the following:

1. Administrative Order No. 4, series 1946, declaring the African giant snail (*Achatina fulica*) a serious plant pest, prohibiting its movement and providing for its control.

2. Administrative Order No. 6, series of 1946, declaring the coconut blight or "kadang-kadang", of virus type, a dangerous disease and providing for its control.

3. Administrative Order Nos. 38 and 51, providing for the destruction of abaca and banana plants infected with root rot and bunchy top, and prohibiting the movement of such plants from infected places or provinces to non-infected ones.

4. Administrative Order No. 39, providing for the eradication of coconut budrot.

5. Administrative Order No. 52 (revised), declaring the black beetle (*Orytes rhinoceros*) to be a dangerous plant pest and the Asiatic red palm beetle, and providing regulations governing the removal and disposal of dead, dying or decaying trunks of coconuts, buri and other palms, trunks of soft woods, sawdust heaps, manure, bagasse, straw and other organic matter or rubbish.

6. Plant Industry Administrative Order No. 4, series 1937, declaring the toy beetles (*Leucopholis irrorata* Chev.) and other allied species hereof, namely, *Anomala* spp., *Lepidiota* spp., *Holotrichia* spp., *Adoretus* spp., and *Alissonotum* spp. dangerous plant pests and providing for their control.

7. Administrative Order No. 5, series 1937, declaring the Florida red scale (*Chrysomphalus aonidum*), the transparent scale (*Aspidiotus destructor*) and other species of scale insects on coconut, dangerous plant pests and providing for their control.

8. Administrative Order No. 2, series 1930, declaring the coconut leaf miner (*Promecotheca cumingii*), a serious pest of coconut and providing for its control.

9. Administrative Order No. 57, series 1928, declaring *Mimosa invisa,* a noxious weed not formerly existing in this country, a dangerous weed and providing penalties for refusing or not complying with the eradication orders.

Under the Plant Quarantine law, we are now inaugurating the enforcement of Plant Industry Administrative Order No. 11, regulating the sales of chemicals used for controlling pests and diseases as well as licensing the people engaged in private and commercial control of plant pests and diseases. The Bureau also enforces Act No. 3251, prohibiting the exportation of abaca seeds and plant and its derivatives to foreign countries. This law has been enforced since the year 1925.

The other laws being enforced by the Bureau covering field regulatory service are the following:

1. Act No. 2945, known as the rat law, which provides regulations for the control of field rats.

2. The locust law, Act No. 2472, which provided for the control of locusts in the populated areas.

3. Act 3163, known as the locust scouting law, which provides for the scouting and control of locusts in the unpopulated or isolated areas.

During the last World War, our Plant Quarantine and Inspection Service suffered serious setback. All of our office buildings, fumigatoriums, warehouses and greenhouses in all ports of entry were burned to the ground. Our equipment, apparatus, supplies and materials, specimens of intercepted materials, of insects, birds and other animals as well as our records and manuscripts, were destroyed, looted or burned. We had nothing to start with after the liberation.

In the year 1945 when our inspection service resumed activities, we started from scratch. We had to improvise an office and be content with what little supplies and equipment we could get hold of. A portion of our office inspection room as well as our remaining fumigatorium had to be rehabilitated in a crude way. We resorted to emergency requisitions of supplies such as fumigants, disinfectants, insecticides and fungicides, which are forwarded direct from America.

Committed to these tasks, we were operating on our old insignificant budget of the past, with appropriation which was not even enough during the pre-war days. At present, with the high cost of supplies and equipment and the increased cost of living and higher wages, our plant quarantine and inspection service worked under heavy handicaps. The huge losses of property caused by the war and disrupted economy necessitated heavy importations of immense quantities of commodities, directly affecting the service.

To the increased volume of work at the ports of entry was added the new service at the airports from the expansion of the aircraft lines extended to the Philippines with Manila as the centre of the aviation routes in the Far East. So, the activities of our service became complicated. The danger of introduction of obnoxious organisms and dangerous pests and diseases is now greater, especially when regular flights are made from countries where dangerous pests and diseases are prevalent, such as the Mediterranean fruit fly (*Ceratitis capitata*), intensifying our concern for their exclusion. Fruits and vegetables coming by ship or airplane from Spain, Italy, certain parts of Australia and Hawaii where this fruit fly is established, are carefully watched and guarded.

To meet the needs for rehabilitation and the increasing demand for plant quarantine and inspection service, additional larger appropriations have to be provided which we could not very well get from special legislation assigning special funds for plant quarantine and inspection service, and so it was decided to ammend our Administrative Order regulating inspection, certification, fumigation and disinfection fees, by increasing the old pre-war fees. The estimated yearly income was made a revolving fund to take care of the need for more personnel, to rehabilitate our buildings and fumigatoriums, and to purchase our supplies and equipment requirements in all the ports of entry for the next five years. Act No. 232 was passed last year appropriating a revolving fund of 200,000 pesetas from the collection of fees realized from services of inspection and certification of incoming and outgoing plants and plant materials and small animals, fumigation, disinfection, disposal of contrabands and other allied services.

The estimated amount for the year from these sources of income runs up from 200,000 pesetas to 250,000 pesetas. With this amount, we are now building an improved and very much enlarged inspection and office building which when finished will be a two-storey building, approximately 8 metres long and 40 metres wide, and gradually building fumigation chambers in all ports of entry.

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A REVIEW OF CANADIAN INSECT PESTS AND PLANT DISEASE LEGISLATION[1]

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Regulatory action by government, preventing the introduction of serious pests and diseases, or in the control of economic pests of foreign origin which have become established in Canada, is comparatively new in the history of Canada, although quite in line with developments of this nature in other countries.

Previous to 1910, no national regulations were in effect and provincial or municipal control was extremely limited and pertained mainly to the control of the San Jose scale in the eastern fruit areas. In that year, following the establishment of an Entomological Branch of the Department, steps were taken immediately to provide legislation which resulted in "An Act to Prevent the Introduction or Spreading of Insects, Pests and Diseases Destructive to Vegetation", known under short title as "The Destructive Insect and Pest Act". The authority for action provided by the Act was wide, the various regulations established over the years on the authority of the Governor-in-Council have been effective in purpose, limited amendments have been required and the status of the Act has never been legally or otherwise questioned.

Only general regulations were passed during the first three years of operation and these were revised in 1914 to provide restrictions against the introduction of hosts of specific insect pests and plant diseases and the enforcement of the regulations by the unit of the Department particularly concerned—Entomology or Plant Pathology, although inspection of imports was assigned to the entomological staff. These revised regulations established ports of importation for certain seasons of the year, where fumigation, or inspection, or both, depending on the nature of the stock, were carried out. Importers were required to notify the Dominion Entomologist before ordering stock, and special ports of entry for European stock were established. Parcel post importations were prohibited.

In 1923 the administration of the Act was completely re-organized. A separate Division was established to administer the regulations which were extensively changed and expanded, and permanent staffs, with seasonal assistants, were assigned to full year ports of importation on the east and west coasts as well as at Montreal, Toronto, Niagara Falls, Windsor and Winnipeg. Fumigation was discontinued except as required, import permits were introduced to ensure control, and certification in the country of origin and re-inspection in Canada were stipulated as a condition of entry.

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[1] Contribution No. 72 Division of Plant Protection.

Certain host species were prohibited entry and others restricted by a requirement of special certification, and certain domestic quarantines were established. The importations affected included all plants for propagation purposes except bulbs and seeds or seed potatoes. However, the general regulations provided authority for the examination of any plant product and for precautionary action as deemed necessary.

During the past twenty-five years regulations have been revised, amended or revoked to meet new developments as they arose. In 1928 flower bulbs were included within the term "nursery stock" and subjected to the standard import procedure. In 1938 the regulations governing the production and sale of seed potatoes in Canada were revised and the administration of the work transferred from the pathological to the inspection service, and in 1948 regulations were established governing the production and sale of certain kinds of flower bulbs produced in the Province of British Columbia. During this period also, major projects have developed in carrying out surveys to determine the distribution of discovered outbreaks of pests and diseases of foreign origin, in the maintenance of quarantine measures and in eradication or control efforts.

Legislation of other countries affecting imports from Canada have been carefully reviewed and summaries distributed to the inspection staffs for guidance, as well as to other Departments concerned, and to the exporters. In an effort to meet these requirements completely, surveys of the special crops affected are carried out during the growing season and the examination of the product at the time of shipment provides a further safeguard in support of health certificates issued for such exports.

Early in the war, on the request of the British Ministry of Food and under the authority of the general regulations of the Act, the inspection of the holds of ships carrying grain or cereal products from Canada was inaugurated. During 1948 the service was expanded to cover all ships, regardless of the country of destination, in order that the high quality of such Canadian produce may be maintained to the time of delivery. It is believed that Canada has exceeded other countries in the degree of protective measures of this kind.

Associated with inspection and the effort to minimize restrictions on imports from other countries, due recognition has been given to the question of treatment rather than rejection. Fumigation facilities are maintained by the Department at the two major seaports—Montreal and Vancouver—and in Montreal the most modern vacuum and atmospheric equipment and facilities have been available for the past fifteen years. The Montreal fumigation plant is also the centre of extensive fumigation research with a specially trained staff striving to devise improved and more effective treatments for insect infested importations of various plant products from distant countries. Insect free importations from other countries are expected, including plant product consignments to Canada, but this hope is far from being realized. In the meantime, based on the species of insect involved and its status as a pest of economic importance, together with the possibility of satisfactory fumigation or other treatment, the policy is to facilitate rather than complicate international trade.

At the present time, the various regulations under the Destructive Insect and Pest Act of Canada are under review from the standpoint of consolidation in conformity with all governmental regulations and to provide certain amendments, revisions and cancellations deemed appropriate in the light of present biological information. A summary of the *proposed* regulations, which it is anticipated will be in effect in the near future, is as follows:

The consolidation draft divides the regulations into: Definitions; Part I — General; Part II — Admission of Plants Into Canada; Part III — the Movement of Plants Within Canada; Part IV — Restricted Exports; Part V — Governing the Production and Sale of Certified Seed Potatoes and Potato Eyes; Part VI — Governing the Production and Sale of Narcissus, Tulip, Iris and Hyacinth Bulbs Grown in the Province of British Columbia.

Part I—General

Prohibits the disposal of infested or infected plants contrary to authority; authorizes under permit the importations of prohibited plants for scientific purposes or movement within Canada for such purposes; stipulates the powers of Inspectors to enter premises including ships and aircraft, provides authority for treatment or destruction when necessary, and authority to refuse certificates for export, and provides protection from interference; provision is made for compensation in very unusual cases but generally requires that all risk, financial and otherwise, shall be the responsibility of the owner.

Part II—A. — Nursery Stock

This Part deals with the procedure to be followed in importing material for propagation involving applications, permits, certification in the country of origin, marking of containers, parcel post procedure, re-inspection in Canada, routing, responsibility of transportation companies and Customs, treatment, charges, etc. The inspection ports in Canada through which importations must be routed are listed, including two extra ports for mail and air express or freight.

B. — Prohibited Imports

Prohibited imports include: potatoes from Europe, the Azores, Canary Islands, Newfoundland, St. Pierre and Miquelon; five-leaved pine, except seed, from all countries; certain species of *Ribes* from all countries; *Larix*, except seed, from countries other than the United States; *Ulmus* and *Zelkova*, except seeds, and their wood with bark attached, from all countries, and *Corylus* into British Columbia from the eastern United States.

C. — Restricted Imports

Restricted imports include: potatoes (*Solanum* spp.) from Pennsylvania, West Virginia and Maryland in the U.S.A., unless grown outside the potato wart disease *Synchytrium endobioticum* (Schilb) Perc. area and so certified and from other countries (except B. above) except under an advance import permit and subject to inspection in Canada and any precautionary action deemed necessary; nursery stock and miscellaneous fruit and other products from the New England States except under special certification for gypsy moth *Porthetria dispar* L. and brown-tail moth *Nygmia phaeorrhoea* Don.; plants with soil from Asia except under special certification; *Castanea* including the seeds from Europe, Asia and the United States except under special chestnut bark disease *Endothia parasitica* (Murr.) A & A certification; barberry, *Mahonia* and *Mahoberberis*, including the seeds, from all countries except varieties determined by the Dominion Botanist as immune to black stem-rust of wheat *Puccinia graminis* Pers.; buckthorn, including the seeds from all countries except species determined as immune to crown rust of oats *Puccinia coronata* Cda.; stone fruit stock from the United States except under special certification for virus diseases; hosts of the Oriental fruit moth *Grapholitha* (*Laspeyresia*) *molesta* Busck. from the United States into British Columbia, except under a fumigation certificate; certain corn products into western Canada from the eastern United States except under special certification on account of the European corn borer *Pyrausta nubilalis* Hubn.; broom corn from countries other than the United States except under fumigation on arrival in Canada or en route in the United States; plants with soil from Hawaii and Puerto Rico except under special certification; fruits and vegetables and other miscellaneous commodities from Hawaii except under special certification by the U.S.D.A.; wheat and wheat products from Australia, Asia, Africa, Bulgaria, Cyprus, Italy, Spain and Chile except under import permit and special certification from the country of origin that the wheat was harvested in a locality where the disease flag smut, *Urocystis tritici* Koernicke, is not known to occur; wheat and its products from certain States of the United States except under import permit and special certification that the material was harvested in a locality where the disease dwarf bunt (race of *Tillitia caries* (D.C.) Tul) is not known to exist but excepting wheat seed being imported for scientific purposes by Governmental Departments, Universities, etc.

The import restrictions also establish extensive and detailed control over importations of living stages of insects, pests or disease, etc. which may directly or indirectly cause damage to vegetation. An import permit is required and all importations are subject to examination before release. Quarantine restrictions after release may be imposed.

Part III—Movement of Plants Within Canada

This Part of the regulations covers the prohibition of the movement of *Corylus* to the Province of British Columbia from any other province of Canada; *Berberis*, *Mahonia* and *Mahoberberis* from any one province to any other province except varieties determined as immune to black stem-rust of wheat, with similar conditions applying to the movement of *Rhamnus*.

On account of the European corn borer in eastern Canada restrictions apply to the movement of corn and certain corn products from eastern to western provinces; the Maritime provinces are quarantined on account of the European apple sucker as applying to apple, pear, quince or European mountain ash stock, except the fruit; the movement of the hosts of the Oriental fruit moth, including the fruit, is prohibited to British Columbia from other provinces and a quarantine is maintained on certain countries in the province of Quebec and in eastern Ontario on account of the Dutch elm disease.

Part IV—Resricted Exports

The only export regulation at present applies to the movement of apples from Eastern Canada to countries other than the United States. A final certificate covering freedom from the apple maggot is required with the Customs export entry and such certificates are based on a procedure established by the regulation involving the practice of apple maggot control in the orchard or in the control zones established together with an inspection of the fruit just before harvest and again during grading operations.

Part V—Governing the Production and Sale of Certified Seed Potatoes and Potato Eyes

Extensive regulations are in effect regarding this activity which is carried out in all suitable seed potato producing areas in Canada, with specialization in production in the Provinces of Prince Edward Island and New Brunswick, where about 80 per cent of the total quantity of seed potatoes are produced. Definite requirements are laid down concerning the growers' responsibility, and at least two and sometimes three field inspections are carried out, together with harvesting and shipping inspection. High standards have been established concerning tolerances for viruses and other diseases as well as for grade defects and no tolerance is allowed for the disease bacterial ring rot *Corynebacterium sepedonicum* (Spilck & Knott) Skapt. & Burk. All seed must be shipped in new containers and must have attached thereto an official Departmental tag indicating the variety and class of seed. There are three classes—"Foundation", "Foundation A" and "Certified", with the lower tolerances applying to "Foundation". The potato eye trade in Canada has developed considerably in recent years and regulations were considered necessary to ensure the use of Certified seed rather than table stock in the cutting of eyes. Official tags or stickers are provided to bona fide firms or growers who are in this business.

Part VI—Governing the Production and Sale of Narcissus, Tulip, Iris and Hyacinth Bulbs Grown in the Province of British Columbia

In 1948 detailed regulations were established regarding the above subject, which were based to a large extent on the seed potato regulations in which provision is made for field, bin, and shipping inspections, limited tolerances for insect pests and plant diseases as well as grade defects, the official tagging of certified crops and provision for "Foundation", "Certified" and "Commercial" classes of bulbs.

The administration of the regulations under the Act is carried out by the Division of Plant Protection of Science Service with the guidance and advice of other units of the Service, particularly the Division of Entomology and Plant Pathology. In addition, all proposed changes in the regulations are subject to careful study by the Destructive Insect and Pest Act Advisory Board, which was established by authority of the Governor-in-Council to advise the Minister of Agriculture on such matters, and which comprises six senior officers of the Department. An effort is made to keep in touch with developments in Canada and in other countries, regarding insect and plant disease problems and to avoid unnecessary restrictions on world trade in products subject to attack by pests and diseases.

DISCUSSION

In reply to Wilson (Australia) it was stated that the fumigation facilities were owned and operated by the Quarantine Service and that there were no special ports of entry for specific articles except in connection with the tourist traffic.

In reply to Dumbleton (New Zealand) it was stated that trained men—entomologists and pathologists—were stationed at the main ports of entry.

QUARANTINE PROBLEMS OF HAWAII

By C. L. Ritchie, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U.S. Department of Agriculture

The vulnerability of Hawaii to the entry of new insect pests by trans-Pacific air traffic has been a subject of serious concern for a number of years. The mild, winterless climate and wide variety of endemic and introduced flora combine to create a particularly favourable environment for establishment of accidental introductions of insects. The truth of this statement is evidenced by the firm foothold attained by over 1,300 species of foreign origin out of a total of about 5,000 known species of insects in Hawaii. True, most of the insects introduced were brought in prior to the advent of the airplane. As a matter of fact, there is no positive evidence that any of these insects came into Hawaii by plane. However, because most insects die from lack of food and water within a few days after leaving their normal environment, the plane is the only carrier capable of bringing such insects to Hawaii quickly enough to permit them to survive unless accompanied by host material.

The position occupied by the Hawaiian Islands in trans-Pacific air lanes has created manifold plant quarantine problems. Insects and plant diseases may be transported into Hawaii from foreign areas and continental United States, pests already established in Hawaii may be carried to the mainland, and foreign pests may be transported through Hawaii to the mainland. Aircraft landing in Hawaii are in close proximity to a wide variety of host plants having no dormant season, and most departing planes arrive on the mainland at airports within richly agricultural areas such as are found in California. Long-range flights, of which there are many, may land at any point within the United States, frequently at airports far removed from plant quarantine inspection stations. This situation has necessitated not only a close inspection of incoming planes but a thorough examination of all baggage, cargo, and commissary stores of those departing for the mainland.

Normal quarantine inspection activities are aimed primarly at infested or infected materials. It is not inferred that the hitchhiker or stowaway is of no import. All factors considered, however, the conclusion appears warranted that introduction of insect stowaways by aircraft is less probable than has frequently been supposed. For example, a mango containing a hundred fruit fly larvae is potentially much more dangerous than a hitchhiking adult, even if gravid.

On the other hand, the stowaway problem could easily be passed over too lightly. Repeated introductions of single specimens could eventually beget establishment. Plant quarantine inspectors in Hawaii are facing just such a possibility at the present time. The safeguarding of aircraft against accidental transporation of destructive insect pests is probably a greater problem in Hawaii than anywhere else in the world, owing largely to the immense buildup in population of the oriental fly, *Dacus dorsalis* Hendel, which became established in the Islands during World War II. Its transmission to the agricultural areas of the United States mainland is an ever-present fear. The basic essentials for solving the stowaway problem are as follows: Prevent the insect from boarding the plane; if it boards, prevent it from surviving the trip; if it does survive, see that it does not reach a likely host.

In Hawaii several safeguards are employed to reduce the population of flying insects in the immediate vicinity of airport areas. Complete sanitation—that is, absence of host material—in the airport area would approach the ideal situation, but at present this is impossible. Persons responsible for terminal facilities are understandably concerned over landscaping, and attempts to rule out all plants have been met with serious opposition. Thus, a compromise has been necessary, only plants producing fleshy fruits being barred from terminal areas. In spite of the sparse vegetation at John Rodgers Terminal and the complete absence of *Dacus dorsalis* hosts, a single trap under a palm tree has collected as many as 2,500 flies in one day. Of course, this collection was at the height of seasonal fly population. Possibly the days of abundance may be attributed to wind currents, rain in the mountains, or some other temporary environmental disturbance. As yet we know little of the flight range of *D. dorsalis.*

Since airport sanitation has given only partial relief in reducing the population of insects in terminal areas, other modes of attack have been necessary. Although trapping operations for *Dacus dorsalis* were not originally intended for population-reduction purposes, our collections have been so high that in recent months additional traps have been added with that in mind. Our present plans include extensive trapping operations as a routine supplementary safeguard. A pressing need in this respect is a more satisfactory lure, one that is specific for *D. dorsalis* females.

Another practice currently employed is the application of residual-type sprays to the various air-terminal buildings, particularly the flight kitchens and cargo sheds. We have not yet determined the period of effectiveness, but the experience of others in using residual sprays in Hawaii has not been entirely satisfactory. Little actual research along these lines has been conducted locally. Some workers have suggested that the high percentage of sunlight hours and prevailing small showers throughout the year may combine to reduce the period of effectiveness of such materials as DDT.

Our most efficacious safeguards against dissemination of insect pests by aircraft consist in thorough inspection by well-trained personnel and the application of an aerosol insecticide to all inclosed portions of the plane. The first procedure, inspection, is aimed at both host-associated insects and plant diseases. Both the plane itself and all baggage and cargo should be inspected. The interception and immediate destruction of prohibited plant material is beyond doubt the most effective of all plant quarantine functions. The quantity of prohibited material carried by aircraft is nothing short of amazing. During the past year, for example, 6,743 prohibited items were intercepted at Honolulu on aircraft arriving from foreign countries in addition to 4,206 items of Hawaiian material taken from planes departing for the mainland.

Even the most thorough inspection fails to eliminate the stowaway insect that may be lodged under the seats, behind the instrument panel, in a light well, or otherwise hidden. The United States Public Health Service, pioneering in means of preventing the introduction of human disease vectors by aircraft, established the use of aerosol bombs on aircraft and approved a formula and dosage that are lethal to house flies and mosquitoes. Use of the same or a similar method seemed to be a possible solution to our problem. Most insects of agricultural importance are not killed by the dosage required by the Public Health Service. Unfortunately, this dosage is very near the upper limit of human tolerance. The obvious solution was to find a more potent human-tolerant formulation or to apply increased dosages of the same formula at a time when passengers and crew were not present. The latter method is being utilized as an interim measure until such time as research personnel of the Bureau of Entomology and Plant Quarantine have developed a more satisfactory procedure. It should be recognized that research workers on this problem are concerned not merely with a formula that will quickly kill resistant species of insects and methods of applying the aerosols, but also with the effect that formula will have on personnel and on the interior surfaces of the plane. Such questions as possible staining of upholstery fabrics, pitting of Plexiglass and plastics, fogging of instrument panels, corrosion of electrical wiring, fire hazard, and persistence of odour must be dealt with effectively. Any new aerosol recommended for our use must, therefore, meet the approval of such other Federal agencies as the Civil Aeronautics Administration, the Military services, and the U.S. Public Health Service.

That our present usage of aerosols for aircraft disinsectization is effective is evidenced by our not having found live insects after such treatment. Our current practice is to make two applications at different dosages. In the case of planes arriving from foreign countries a Public Health dosage of an aerosol is applied before passengers deplane if such an application has not been made by flight personnel within thirty minutes prior to landing. This application will knock down insects of agricultural importance to prevent their escape while passengers deplane. Immediately after passengers deplane, a second and much heavier dosage is given to complete the kill. For planes departing for the continental United States, the order of the two treatments is reversed. About forty minutes before take-off the heavy dosage is applied, and after the passengers are aboard a lighter dosage is given. All treatments, of course, are given to cargo as well as to passenger compartments, and no distinction is made between civilian and military aircraft.

In these few paragraphs we have reviewed briefly the more important quarantine problems affecting Hawaii, most of which are peculiar to airborne traffic. Not only are we concerned with the protection of Hawaii against pest introduction, but we are also responsible for keeping plant pests of foreign and Hawaiian origin from reaching the shores of the mainland and spreading pests among the Pacific Islands.

That a single introduced species can seriously affect an agricultural area is demonstrated by the losses to Florida fruitgrowers caused by the Mediterranean fruit fly in the late 20's. That property loss was estimated to be in excess of 7,000,000 dollars and involved a relatively small area of infestation. An agricultural economy could not long survive such losses. The effectiveness of aircraft disinsectization, sanitation at terminal sites, and other discussed procedures is an essential contribution to the maintenance of a sound agricultural economy.

DISCUSSION

In reply to Smith (California) it was stated that the use of residual sprays against insects in passenger compartments of planes was not at present satisfactory owing to the removal of deposits in cleaning operations.

In reply to Wilson (Australia) it was stated that the baits used to trap *Dacus dorsalis* did not attract flies from more than 100 yards distant.

Salmon (New Zealand) mentioned the arrival in Australia on a flying boat of a living New Zealand weta *Hemideina* sp.

Replying to Dumbleton (New Zealand) it was stated that all Quarantine operations were carried out by Federal Agents of the U.S.D.A. who also acted for the Public Health Service.

Replying to O'Connor (Fiji) it was stated that the inspection of passengers' baggage was a Customs Department responsibility but quarantine officers were present during inspections.

ENTOMOLOGICAL ASPECTS OF INSECT QUARANTINE IN NEW ZEALAND

By L. J. DUMBLETON, Entomology Division, Department of Scientific and Industrial Research, New Zealand

THE economy of New Zealand is based on the export of primary produce. The country has a climate which is particularly favourable for the grassland farming which is the basis of our primary production. The production, per person engaged in the industry, is probably as high as anywhere else in the world. New Zealand thus starts with considerable advantages which help to offset the disadvantage of distant markets. Anything which reduces production or increases the costs of production means that our products compete on less favourable terms. Many of the factors which influence the margin between production costs and market prices are not under our control. There is, however, one factor which is to a large extent under our own control and that is the insect factor. I refer more particularly to the insidious and continuing establishment in New Zealand of new pests from overseas. No criticism is intended here of the administration of the quarantine laws as I am not sufficiently well informed on the operation of the quarantine. What I wish to do is to stress the mounting list of introduced pests and to suggest that the quarantine system should be reviewed as soon as possible in order to increase its effectiveness in preserving our natural advantages in primary production.

We have our native pests and these must be accepted and controlled to the best of our ability. The major pests of man in New Zealand—mosquitoes and sandflies (*Simuliidae*)—are native species, but the only native pests of livestock are some of the sheep maggot flies or blowflies (*Calliphoridae*). The two outstanding pests of pasture, the grass grub *Odontria zealandica* (*Melolonthidae*) and the subterranean caterpillar *Oxycanus cervinatus* (*Hepialidae*) are both native. Another native pest of pastures and crops is an armyworm *Persectania ewingi*. Native species which are pests of horticulture include leaf rollers (*Tortricidae*), Bronze Beetle *Eucolaspis brunneus* (*Chrysomelidae*), Raspberry Bud Moth *Carposina adreptella* (*Carposinidae*) and Lemontree Borer *Aemona hirta* (*Cerambycidae*). The main pests of the native fibre plant *Phormium tenax* are native moths. There are numerous pests of native forest trees and timbers and a few minor pests of exotic forest trees. The native longhorn beetle *Ambeodontus tristis* (*Cerambycidae*) is an important pest of house timbers and there are also native drywood termites.

The great majority of our insect pest species are introduced and it is this category of our pest fauna which is continually being augmented. New Zealand is, however, still in a relatively fortunate position. We have no insect transmitted diseases of man or of animals. In general we are free of widespread catastrophic outbreaks of insect pests except perhaps for the grass grub. Our grasses and clovers are still relatively free from serious introduced pests as also are many of our crop plants such as the potato. The extensive exotic forests—mainly *Pinus* species—are remarkably free of serious primary pests.

That this condition is unlikely to continue is shown by the following lists of insects which have been recorded in New Zealand, for the first time during the past two decades. It is not suggested that the lists are complete. In some cases the insects may have been present for many years but have a slow rate of increase and spread. In other cases they are obviously recent establishments.

1929-1939

Hylastes ater—Pine Bark Beetle. A pest of young pines.

Listrodes obliquus—Vegetable Weevil.

Maleuterpes spinipes—Dicky Rice Weevil. A pest of citrus.

Coptocercus rubripes—Eucalyptus longhorn.

Heteronychus sanctae-helenae—Black Beetle. A pest of maize, paspalum and vegetables.

Hyperodes griseus—Argentine Stem Weevil. A pest of wheat.

Pantomorus godmani—Fullers Rose Weevil.

Priophorus tener—Raspberry Sawfly.

Pontania proxima—Willow Sawfly.

Pieris rapae—White Butterfly. A pest of crucifers.

Psila rosae—Carrot Rust Fly.

Cuspicona simplex—On potatoes and tomato.

Ceroplastes simensis—Citrus wax scale.

Smynthurus viridis—Lucerne Flea.

1929-1949

Pantomorus leucoloma—White Fringed Weevil. Pest of vegetables.

Phleosinus cupressi—Cupressus Bark Beetle.

Otiorhynchus ovatus—Strawberry Root Weevil.

Phalaenoides glycinae—Black Vine Moth.

Vespula germanica—European Wasp.

Nezara viridula—Green Vegetable Bug. A pest of beans, tomatoes, etc.

Metoponia rubripes—Australian Soldier Fly. A pest of maize.

Halotydeus destructor—Red Legged Earth Mite. A pest of vegetables and flowers.

Coptotermes spp.—Australian Termites.

In most cases one can only speculate on the origin of these pests. The majority of the species listed occur in Australia and the probability is that our infestation originated from there.

There are of course other possible sources for some of these insects. The Green Vegetable Bug occurs in the Cook Islands from which New Zealand imports fruits, etc. We could well do with a better knowledge of the citrus pests existing in the Cook Islands than we now have.

Attempts at eradication are under way in the case of two species—the Australian termites and the European Wasp. The possibility of eradicating the Red Legged Earth Mite was carefully studied but it was not considered to be practicable. In other cases such as the White Butterfly and the Green Vegetable Bug eradication could well have succeeded since the insects were either large and conspicuous or restricted to certain food plants and were of restricted distribution when first discovered.

Many insect pests can be imported on or in products which have no necessary relation to the normal life of the insect but in other cases the probability of introduction can be very much reduced by compulsory treatment (such as fumigation) of the product imported before it leaves its country of origin. Assuming that this is done in the cases where it is obviously indicated and that the quarantine inspection at the ports of entry in New Zealand is as efficient as it is practicable to make it, there still remains the problem of dealing with those insects which do evade the quarantine and establish in New Zealand.

Without an accurate stocktaking of the introduced pests which now exist in New Zealand, and their distribution in the country, we cannot decide whether any particular insect is newly established. Our information in this respect needs to be brought up to date. Surveys of the existing pests of particular crops or crop plants should be relatively easy, but the detection in the early stages of pests which are general feeders is more difficult. The primary responsibility for these surveys lies on the entomological organization but in this it is very materially assisted by the specimens sent in for identification by the field officers of many Departments and by private individuals.

When it is demonstrated that an insect pest is new to New Zealand, very careful consideration should be given to its probable status as a pest in this country. Some insects, even if established for a very short time, may give clear indications of their probable seriousness. Some assistance in forming a judgment may be given by the record of the pest in overseas countries and by the facts of its biology and ecology where these are known.

Comparisons of climatic factors in New Zealand and in overseas countries where the pest occurs may be useful, especially if the critical values of these factors for the insect are accurately known. Often however it is impossible to assess precisely all of the factors which determine whether an insect will be a serious pest in a new environment. In the case of a potentially dangerous insect it is rarely that the information on the ecology and climatic requirements of the insect is so precise that one can confidently use such forecasts of probable seriousness as a basis for determining policy as regards eradication.

Since insects which are not serious pests in their country of origin may become so in New Zealand, it is necessary to allow a wide margin of safety in deciding whether to attempt eradication. In the past we have perhaps been too much inclined to regard the establishment of a new pest as a fait accompli. It would I believe be better to regard all new insects as guilty until their innocence is proved rather than, as at present, to regard them as innocent until they are proved guilty. A more positive attitude towards eradication together with an efficient insect pest intelligence system would do much to ensure that we are not burdened in perpetuity with pests which could have been eradicated if they had been discovered early enough and vigorous action taken against them.

Discussion

Pemberton (Hawaii) mentioned the useful part played by light traps in Hawaii in giving early proof of the presence of newly introduced insects.

THE PLANT QUARANTINE SYSTEM IN NEW ZEALAND FROM THE ENTOMOLOGICAL POINT OF VIEW

By A. M. W. Greig, Horticulture Division, New Zealand Department of Agriculture

Introduction

The Horticulture Division of the Department of Agriculture administers the principal Quarantine Acts and regulations in New Zealand and on behalf of the Department, this paper on the plant quarantine system in this country is being presented.

Only from 1st December, 1948, was I personally associated with the administrative problem of plant quarantines and already I realize how involved and complicated is the whole subject. Regulations regarding the importation of fruit or plants into New Zealand were printed in bulletin form in 1918—over 30 years ago—and since that date alterations have been made so that today there are instances where the accepted practices do not correspond with the legal position, so if the practices are sound the law requires alteration; whilst, if they are unsound they should cease as soon as practicable. It has therefore been of immense value to me to have my attention drawn to University of California Bulletin No. 553 of July, 1933—"The efficacy and economic effects of plant quarantines in California". I accept the report of the Special Committee on this subject as a scientific analysis of the situation as it existed in California 15 years ago and I believe it will give us all a balanced approach to this subject if we use abstracts from this bulletin as a foundation for the discussion on plant quarantines. The Chairman of the Committee to which I refer, was Professor Harry S. Smith of the University of California citrus experimental station, Riverside, and I understand that Professor Smith is present here today.

Because this subject is placed on the agenda in the Zoology section I have given this talk the heading "The Plant Quarantine System in New Zealand *from the entomological point of view*", but the diseases of plants are so inter-related that I feel we must consider fungous diseases, bacterial and virus diseases as well as insect pests.

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DEFINITION OF PLANT QUARANTINE

The 1927 New Zealand Introduction of Plants Act defines plants as any viable plant and includes the seed of any viable portion of a plant. In the New Zealand Importation of Fruit and Plants regulations under the above Act the definition of fruit and plants is very wide, fruit being the edible product of any plant and includes the peel, skin or shell of such product and also the seeds of such plant, whether attached to the plant or not, and plant means any tree, flower, shrub, vegetable or other vegetation. Plant quarantine as defined by the Committee reads "Legal restrictions on the movement of commodities for the purpose of preventing or delaying the establishment of plant pests and diseases in areas where they are not known to exist. Under the term "plant quarantine" there might also be included regulations designed to aid in the extermination or eradication of newly established plant pests and diseases.

I am using these terms as thus defined.

THE NATURE OF THE PROBLEM

So as to obtain a general picture of the nature of this problem I propose to summarize the points made by the Committee, namely:

1. The problem is economic as well as biological.

2. It has national and international implications.

3. There is a danger of ineffective and hampering regulations without adequate gain unless the quarantine procedure is on a scientific foundation.

4. Not only must plant quarantine be sound biologically but peoples in other places must believe they are sound.

5. For implementation they are dependent on public support, therefore quarantines applied to minor products must be equally as sound as those applied to major products.

6. They are sometimes used for artificial trade barriers. This is not an honest application of the principle of plant quarantine—an unsound plant quarantine is a trade barrier disguised as a quarantine.

7. Their purpose should be to benefit all of society and not any particular group.

8. The problem is generally presented to the public as a measure to benefit the producer. More abundant production at lower cost also benefits the consumer.

9. The real cost to society of plant pests and diseases is the amount of additional effort required to produce agricultural products on account of these pests and diseases. It cannot be measured in £ . s . d or dollars and cents.

10. A pest or disease often appears more serious to those without it, than to those with it.

11. It is obviously impossible to prevent every introduction of a new disease, but a greater number of factors must combine for a pest or disease to become established. This is often not realized.

These points illustrate the complicated nature of the plant quarantine problem.

NEW ZEALAND AS ADAPTED FOR PLANT QUARANTINE

New Zealand consists of three distinct islands—the two principal ones, North and South Islands being separated by 1200 miles of ocean from the nearest large land mass, Australia.

No case is known in historical times where any plant disease has crossed such an ocean without man's help and there are few cases with insects, therefore, New Zealand is safe from the natural distribution of pests and diseases from overseas and is ideal for the development of an effective plant quarantine. Man himself is the limiting factor. From the point of view of today's civilization, New Zealand is only 100 years old. New Zealand could have been a horticultural paradise from the disease aspect had today's knowledge been available and applied 100 years ago. With the introduction of economic plants, the diseases associated with them arrived as stowaways. Once having entered, conditions within New Zealand, high humidity and medium to fairly high temperatures—were the very conditions most suited for the development of pests and diseases and we have illustrations of the fact that pests and diseases are often more important in a new country than in the country of origin—for example, Nassella tussock; European wasp, *Vespa germanica*.

FOUNDATION OF HORTICULTURE DIVISION—EARLY ENTOMOLOGICAL PROBLEMS AND START OF QUARANTINE

The control of horticultural pests and diseases and a check up on the introduction of new ones formed the foundation of the New Zealand Horticulture Division of the Department of Agriculture.

The department was constituted in 1892 by the amalgamation of the Stock Department and the agricultural branch of the Lands and Survey Department. Up to 1892 the Stock Department had been responsible for the eradication of diseases in stock and suppression of the rabbit pest. The Horticulture Division commenced in 1893 with the appointment of Mr. T. W. Kirk as Acting Biologist and that this division was founded on plant quarantine problems can be seen from the following extract from Mr. Kirk's report of 1894:

"Unfortunately some indigenous species of insects have acquired a taste for cultivated plants and fruit in preference to their original food, but the greater number are imported and that this importation is still going on is amply proved by the examination of almost any shipment of plants or fruit." He continues: "Constant importation of fresh blood gives ever renewed vigour to these enemies and thus enables them to spread and take up fresh ground."

He made some recommendations to meet the situation as it existed, namely:

(a) The prohibition of all trees, plants or fruit infected with any insect pest or fungous disease.

(b) The energetic and unanimous action of all fruitgrowers and gardeners to control disease and the prevention of packing and marketing diseased plants and fruits.

He concludes with this statement: "If this importation of infected plants and fruit were prohibited a lasting benefit would be conferred upon the whole country and the necessity for legislation avoided. Is it too much to hope for such unanimous action on the part of all interested? If so—legislation must follow".

Mr. J. C. Blackmore in his report of 1894 mentions the presence and spread of the codlin moth—*Cydia pomonella* which was then reported as present from Central Otago to Akaroa. The next year a proclamation was issued prohibiting the introduction of fruit or fruit cases in which any trace whatever of codlin moth was found. At this period H.M. Customs inspected imported plants and in 1894 referred doubtful specimens to Mr. Kirk.

In 1896 the "Orchard and Garden Pests Act" was passed. This Act gave power to deal with imported fruit but no power concerning the transit and sale of codlin moth infested fruit within New Zealand, thus it continued to be spread throughout the country.

In 1897 citrus fruit from Australia infested with scale and Queensland fruit fly were prohibited. Inspection of fruit was done by Mr. Kirk and his two pomologists at Auckland, Wellington, Lyttelton, Dunedin and Bluff—fumigating sheds were erected at the four chief ports and fumigation was standard practice by 1900.

At this date all imported trees, fruit and plants were subject to inspection and fumigation with hydrogen cyanide under "Orchard and Garden Diseases Act 1896".

Australia fruit flies are recorded as having been found in peaches, mandarins and oranges arriving at Wellington in 1898.

By 1905, 24,000 fruit trees from Europe as well as bulbs, fruit, vegetables and pine trees were being thoroughly inspected and when necessary destroyed.

It can be seen, therefore, as in other countries that it was the experience of fruitgrowers which turned attention to the need for plant quarantines.

New Zealand horticulture is based almost entirely upon introductions from overseas—namely Great Britain and Europe, U.S.A., South America, Australia and South Africa. Through these necessary importations we have introduced most of the common pests and diseases associated with these plants and the passage of the first 50 years of colonization brought a belated realization of the necessity for curbing this undesirable form of immigration.

THE PRINCIPAL ACTS ADMINISTERED TODAY BY GOVERNMENT DEPARTMENTS IN RELATION TO PLANT QUARANTINE

1. *Orchard and Garden Diseases Act*, 1928 (1896-1908, consolidated 1928) (Agriculture Department). An Act to consolidate certain enactments of the General Assembly relating to orchard and garden diseases.

Under this Act there is power to gazette regulations prohibiting absolutely or defining conditions under which any plant or insect may be imported; defining the ports of entry, appointing quarantine grounds and listing of schedules of diseases.

Specific regulations related to this question under this Act are: The Importation of Fruit and Plants regulations 1915 and Amendments. Regulations relating to the export of fruit.

2. *Introduction of Plants Act* 1927 (Agriculture Department). An Act to control or prohibit the introduction of harmful or new plants into New Zealand.

Under this Act no person shall import any plant which has been declared a noxious weed under Noxious Weeds Act 1928 and particular mention is made of the water hyacinth (*Eichhornia speciosa*). The importation of any plant not commonly grown in New Zealand requires a written permit from the Minister of Agriculture who may make such conditions as he thinks fit.

3. *Seeds Importation Act,* 1927 (Agriculture Department). An Act to regulate the importation of certain seeds and in particular to require the treatment of imported seeds to distinguish them from New Zealand grown seeds. Seed means cocksfoot, lucerne or white clover seed or any seed gazetted from time to time—ryegrass later added. This is more a trading Act than a quarantine one.

4. *Apiaries Act,* 1927 (1907 consolidated.) (Agriculture Dept.) An Act to consolidate and amend the law relating to the bee industry in New Zealand. Regulations may be made under this Act for the prohibition or regulation of the introduction into New Zealand of any bees, honey, comb foundation or other appliances which are likely to introduce any disease into New Zealand.

5. *Customs Act,* 1913 (Customs Department). Prohibition on imports of oranges, bananas, kumaras, onions except through the Marketing Department.

6. *Forests Amendment Act,* 1948 (State Forest Service). This Act principally refers to timber trees and timber, but the powers in some instances are identical with the Orchard and Gardens Diseases Act, 1928, i.e. no person shall import into New Zealand any tree, tree-seed, timber or timber product which may introduce any insect, fungus, bacterium or virus in any of the life stages of those organisms that may be injurious to any tree, tree-seed, timber or timber product and no person shall export from New Zealand any tree, tree-seed, timber or timber product.

7. *Fireblight Act,* 1922 (Agriculture Department). An Act to make special provision for the control of the disease of fruit and other trees known as fireblight. This Act was to prevent the spread and endeavour to eradicate fireblight and in particular to authorize under regulations the trimming or cutting down of all hawthorn in commercial fruitgrowing districts.

THE ADMINISTRATIVE CONTROL OF PLANT QUARANTINES IN NEW ZEALAND UNDER GOVERNMENT DEPARTMENTS

1. *Agriculture*: Horticulture Division with which is associated the Plant Diseases Division of the Scientific and Industrial Research Department which supplies technical expert advice on all diseases of plants.

2. *The State Forest Service,* with which is associated the State Advances Corporation and Cawthron Institute. The State Forest Ser-

vice is primarily concerned with timber and timber trees. Tree seeds being imported are fumigated for two hours with carbon disulphide 1 oz. to every 100 lb. seeds. The seed of the Douglas fir for export is similarly treated.

All ships bringing Australian poles or sleepers into New Zealand are inspected by the State Forest Service for any sign of termites. If found infected the timber is taken to an inspection department where a more thorough inspection is carried out. Timber badly infested is destroyed and the balance is treated with creosote under pressure.

The State Advances Corporation, supported by advice from the Cawthron Institute, endeavours to check the spread of termites in New Zealand which I believe are confined to Auckland and New Plymouth. Termites are disturbed as little as possible and then arsenical spraying is done to exterminate a colony.

3. *Internal Affairs*: The Internal Affairs Department under gazette notice of 16th January, 1936, prohibits the importation of insects, including insect eggs and insects in their larval, pupal and adult stages and spiders and scorpions and the eggs of spiders and scorpions. For an exception to this rule the consent of the Minister of Internal Affairs must be obtained.

4. *Post Office and Customs Department*: The Post Office refers the export or import of any plant through parcels post to the Horticulture Division and an examination is made by an Inspector at the parcels post office.

The Customs Department through its tariff powers is closely associated with the Horticulture Division for import and export permits, but the plant quarantine aspect is the responsibility of the latter division.

5. *Co-ordination*: Although several Government Departments are involved, in my opinion there has been the closest collaboration amongst them and the differences which arise from time to time are no greater than differences which would arise even if all personnel were within one fully equipped "Plant Quarantine department".

THE PLANT QUARANTINE SERVICE AS IT IS TODAY

Before dealing in detail with the plant quarantine service as carried out by the Horticulture Division it is desirable to make a quick review of the various systems which may operate.

A. *Inspection at Point of Destination*: The first system put into practice was inspection at point of destination. It is, however, physically impossible to examine all material with the necessary care and in many instances it is impossible to detect a disease even with the most careful microscopic examination. There are inconspicuous stages in the life cycle of insects such as scale insects or no external evidence of the presence of a pathogenic organism.

A sound quarantine will not allow the entry of host plants and host fruits from an infested area only because inspection failed to show the presence of disease. The only safe method is a total embargo against all host fruits or plants of a specific pest or disease. Such fruits or plants should be declared contraband and inspection should be limited to search and seizure of such contraband.

B. *Inspection and Certification at Point of Origin*: Most importing countries now require that all plant material before export must be examined by an appropriate Inspector and the produce then accompanied by a certificate. This system is open to the same criticism as the first method—the physical impossibility of detecting many plant diseases and pests. It is also more open to fallibility as human nature is generally less interested in the disease aspect of exports than of imports.

It is therefore concluded that plant quarantines cannot be made effective by inspection of plants or plant products either at origin or at destination.

C. *Complete Embargoes*: Complete embargoes require little consideration. All trade in plants and fruit would cease if embargoes operated and these are only justified against the most serious plant diseases.

4. *Controlled Introduction of Plants and Plant Products*: The system of controlled introduction is one varying for each product or country according to conditions. In general importations are restricted to products from an uninfested area with treatment by fumigation or other methods as an additional safeguard. With dependable data and a reliable organization at the exporting as well as at the importing end, this system is sound.

E. *Swingle, Robinson and May Method*, 1924: Swingle, Robinson and May outlined the following method:

Obtain from a locality free from certain specific pests and diseases a limited amount of propagating material—nursery stock, plants, scions or cuttings. Inspect this material carefully and then forward to importing country where the plants are again carefully inspected and then planted out in an isolated locality for a preliminary period for observation. After a period of years when completely satisfied regarding freedom from disease—propagate on a commercial scale.

This method applies in particular to plants but it is very important because there are few instances where commercial fruit forms a very important carrier of plant diseases. In most instances nursery stock-bulbs, tubers, roots and cuttings are the most dangerous carriers of pests and diseases. For instance scale insects on fruits are less likely to become established in a new locality than when closely associated with their host plants.

The Swingle, Robinson and May method has therefore a definite place in a sound plant quarantine.

The New Zealand Plant Quarantine Service. The administration of plant quarantine Acts and regulations is usually done by the Horticulture Division, Department of Agriculture. Unlike the U.S.A. or Australia there is no problem relating to State functions and Federal functions as there is only one Dominion, or New Zealand, Department of Agriculture.

The Horticulture Division has its headquarters at Wellington, the administrative officers being a Director and Assistant Director at Wellington and Horticultural Superintendents at Auckland, Palmerston North, Nelson and Dunedin. The division provides an instructional or advisory service to fruitgrowers, commercial gardeners and beekeepers, as well as carrying out inspectional duties associated with disease control and the grading of horticultural crops. There are 38 Horticultural Inspectors—the principal Horticultural Inspector being stationed at Wellington. The plant quarantine service is a direct responsibility of the Inspectors, who carry out port inspection duties as well as auction market and field duties. The main ports of entry are Auckland, Wellington, Lyttelton, Dunedin and Bluff. Only at Auckland and Wellington is there an Inspector who is practically full time on port inspection duties. Sub-ports where plants may be landed if a ship arrives direct from overseas are Gisborne, Napier, New Plymouth, Nelson, Timaru and Oamaru.

New Zealand's system of plant quarantine is controlled introduction of plants and plant products. It is based on one or other of the following porcedures or a combination of several methods.

A. Complete embargoes.
B. Partial embargoes.
C. Inspection before despatch and accompanying certificate.
D. Inspection on arrival with:
  i. Reshipment or destruction.
  ii. Treatment.
  iii. Direct release or release under quarantine.
E. Eradication of major pests.
F. Control.

A. *Complete Embargoes*: Complete embargoes apply as follows:

Fruit from any country where Mediterranean fruit fly is known to exist.

Apple, Pear and Quince Trees—from any country where Fireblight exists.

Citrus Trees—from any country where Citrus canker exists.

Raspberry Canes—from any country.

Hop Sets—from any country.

Kumaras—from any Pacific Island where white-spotted kumara-weevil or sweet-potato-weevil occurs.

Noxious Weeds—from all countries, in particular water hyacinth and *Tourretia volubilis*—Bignoniaceae—a half hardy twining plant, a native of Peru.

B. *Partial Embargoes*: Partial embargoes apply in certain instances—for example Citrus from irrigation areas of New South Wales may enter New Zealand but Citrus from coastal districts must come from clean orchards at least 1 mile away from the nearest fruit fly recorded orchard. Citrus from Fiji and Cook Islands is accepted provided an annual certificate is received that Mediterranean fruit fly does not exist on the islands and fruit has been held for a minimum period of seven days in an insect-proof enclosure so that all other fruit flies may have hatched out. Grapes as fruit from Australia, U.S.A. and Canada may be imported provided they are disease free and grown on a vineyard at least five miles away from any downy-mildew or phylloxera recorded vineyard and no grape vine foliage or wood is attached. Citrus trees from Australia may only enter if nursery on which raised is certified free from citrus root rot. Straw packing from Australia if it is the produce of Victoria, South Australia and Tasmania or outside cattle tick infested area of New South Wales.

C. *Inspection Before Despatch and Accompanying Certificate*: Fruit or plants arriving at New Zealand ports of entry must be accompanied by one or more certificates from the Inspector at the country of origin. These certificates deal with the condition of the fruit or plants, freedom from disease or origin from areas certified to be free from certain diseases. The wording of these certificates is of interest: "I hereby certify that I have duly inspected the consignment of . . . addressed to . . . and consigned by . . . and have found them to be, *to the best of my knowledge*, clean and free from disease." In another case the word *apparently* replaces those in italic.

The fumigation and dipping certificate to accompany plants or portion of plants to New Zealand reads: "I hereby certify that the consignment of . . . addressed to . . . and consigned by . . . have been subjected in a suitable enclosure to the fumes of hydrocyanic acid gas for the space of one hour" (or have been sprayed with or dipped in Bordeaux mixture) (or have been sprayed with or dipped in red-oil emulsion mixed in the proportion of one part red oil to twelve parts of water). In most instances fruit is required to be packed in clean new packages.

Until the necessary certificate is in the hands of the local port Inspector it is not customary to make any inspection of the fruit or plants.

D. *Inspection on Arrival and Treatment Procedure*: On arrival at port of entry, the Horticultural Inspector having found that the necessary certificates are in order, proceeds to inspect the consignment. The general procedure with fruit is to inspect 5 per cent of the first 100 cases in a consignment and 1 per cent for each additional 100 cases. Island oranges are generally completely repacked in Auckland under supervision. With plants or bulbs it is usual to inspect as many cases or packages as an Inspector thinks necessary in order to obtain a fair coverage of the various kinds of plants in a consignment. The same applies to parcels held at Parcels Post Offices, although in general all parcels are completely inspected. The various diseases recorded have been classified and placed in certain schedules in the regulations. The 12th Schedule consists of insects pests—i.e. San Jose scale, *Aspidiotus perniciosus*, and other scale insects, mealy bug, *Icerya purchasi*.

Fruit or plants infected with diseases listed in the 12th Schedule are fumigated by the Inspector using hydrogen cyanide and a fee is charged for fumigation. The 13th Schedule consists of bacterial diseases and the more serious insect pests, i.e. Citrus canker—*Pseudomonas citri;* Fireblight—*Bacillus amylovorus;* Mediterranean fruit fly, *Certitis capitata.*

Fruit or plants infected with diseases listed in the 13th Schedule are destroyed under supervision of the Inspector at the port of entry and the cost of destruction is paid by the owner.

The 14th Schedule consists of fungous diseases and certain insect pests, i.e. wither tip of citrus—*Glomerella cingulata;* collar rot of citrus—*Fusarium limonis;* red mite, *Paratetranychus telarius.* Fruit or plants infected with diseases listed in the 14th Schedule may be dipped under the directions of the Inspector, but in practice few diseases are classified in this Schedule.

The 15th Schedule consists of fungous and bacterial diseases and insect pests, i.e. downy mildew of the grape—*Plasmopora viticola;* phylloxera of the grape—*Phylloxera vitifoliae*; sweet potato weevil, *Cyclas formicarius.* Fruit or plants infected with diseases listed in the 15th Schedule are either reshipped at once to a port beyond New Zealand if an Inspector consents or destroyed at the cost of the owner.

If in doubt regarding the identification of any disease he forwards a specimen direct to the Plant Diseases Division, Scientific and Industrial Research Department, Auckland, and holds the consignment until the disease is identified and action determined accordingly.

Fumigators owned by the Department of Agriculture are situated at the four main ports of entry: Auckland, Wellington, Christchurch (not Lyttelton) and Dunedin. They vary in size from a capacity of 200 sacks of grain at Auckland down to 50 sacks capacity at Christchurch.

The principal products requiring fumigation are grass seeds, maize, barley, wheat, oats, peas, nuts, pineapples, citrus fruits, other fruits and a few plants. The number of packages fumigated varies considerably from year to year, depending on volume of imports and insect pests present. Auckland fumigator put through 2,331 units in 1945 and 29,692 units in 1944—whilst Wellington figures were 695 units in 1945 and as low as 13 in 1943. Auckland figures include the fumigation of local stocks as well as imports. Fumigants used are:

Hydrogen cyanide for scale insects on fruit and plants.

Carbon disulphide for weevil and mite in grain and seeds.

The practice for hydrogen cyanide fumigation is to use earthenware bowls in which there is a small quantity of water and add one-third quantity sulphuric acid and then the potassium cyanide is dropped in —1 oz. of cyanide being required for 1,000 cubic feet capacity.

For plants fumigation requires about two hours by this process, but a longer period is used for other products—fruit with scale, etc. With carbon disulphide 8 lb. of carbon disulphide is used per 1000 cubic feet, being poured into a hollow in the sacks to be fumigated and then left for 24 hours. These fumigants are highly poisonous and this aspect of port inspection is a very responsible one for the Port Horticultural Inspector.

Quarantine Stations. Release under a limited form of quarantine is practised. New Zealand has no plant quarantine stations and when plants are released under quarantine the owner signs a declaration that the plants will be planted under inspection, will be under review for a period and will not be lifted or disturbed until authority is granted. This system has operated when people through ignorance imported plants without the necessary certificate, but which would otherwise have been permitted to land.

Raspberry, loganberry and boysenberry as well as currant plants have been imported under this quarantine procedure, and are generally planted on owner's properties. Seed potatoes in lots not more than 12 lb. are imported and grown under a similar declaration in quarantine and dug in the presence of an Inspector. Before distribution the written consent of the Director must be obtained. The quarantine principle is adopted in the citrus growing districts when an outbreak of citrus canker occurs.

E. *Eradication*: The policy of eradication has rarely been attempted in New Zealand. Based on overseas results in Florida and South Africa an attempt is proceeding for the eradication of citrus canker, *Pseudomonas citri*, from the country. This disease was first identified in 1937 and up to December, 1948, over 4,000 citrus trees and 12,000 citrus nursery trees had been destroyed either because they were actually infected or were in the vicinity of infected trees. Special regulations were issued in 1940 and under these regulations the principle of compensation was first established here for any plant product although it had previously existed for livestock. Another instance where eradication is being attempted is with the European wasp, *Vespa germanica*, first discovered in New Zealand in 1944.

F. *Control*: Control measures have been standard practice in New Zealand over the past 50 years. They have principally consisted of inspection of fruit tree nurseries and orchards; an improved scientific service for disease identification, certification of therapeutants and research into the most efficient dilutions at which certified therapeutants should be applied. This work has been carried out by the Plant Diseases Division, Scientific and Industrial Research Department, Auckland, and the technical information is carried to producers by the Horticultural Instructors of the Department of Agriculture.

A special quarantine applies to the importation of honey bees and this system appears to approach the ideal quarantine—it excludes certain major diseases with little cost of enforcement and no interference with commerce or travel. Unfortunately, however, all these safeguards have not prevented the introduction of the European wasp, *Vespa germanica*.

The system for honey bees is as follows: The bees must first of all be examined by a responsible Government officer whose technical duties relate to apiculture in the country from which the bees are exported. If free from disease it is certified that such bees are free from disease and that the bees have immediately prior to export been kept on an apiary that is free from all bee diseases including the very serious ones—Foulbrood, *Bacillus larvae* and *Bacillus pluton;* Bee louse, *Braula coeca;* Isle of Wight or Acarine disease, *Acarapis woodi*.

This ensures that the bees have been drawn from stocks free from brood diseases which are readily detected by visual examination. The queen bee and 15 to 20 escort worker bees, together with sufficient candy for the journey, is then placed in a small mailing cage which must be addressed to the importer by name only, c/o the Superintendent, Wallaceville Animal Research Station, Hutt Valley, Wellington. On arrival all escort bees are removed and dissected and the tracheae examined under a microscope for "Acarine" disease and a general examination for bee-louse. If any bee in the consignment is diseased all the bees, including the queen and containers, are burnt. If no disease is found, all the remains of the worker bees and imported containers are still burnt but the queen is transferred to a new container and 15 to 20 New Zealand worker bees are placed in the container too, and accompany the queen as an escort on the next stage of the journey to the importer. Any bees or appliances arriving without a permit or in accordance with the above procedure, if detected, are seized and destroyed by an Inspector. The Post Office and air service in New Zealand co-operate by holding any consignments not addressed to Wallaceville Research Station.

Some Major Pests Not Yet Recorded in New Zealand:

Mediterranean fruit fly.
West Australian fruit fly.
Cattle tick.
Colorado beetle.
Downy mildew of grape.
Sweet potato weevil.
Spotted kumara weevil.
Citrus root rot—*Phytophthora citropthora*—on roots of citrus nursery stock.
Bee louse of bees.
Isle of Wight disease of bees (Acarine disease) *Acarapis woodi*, a mite which enters the respiratory system, causes irritation, paralysis and death. Occurs in U.K. and parts of Europe.

Other Major Ones, to Check Further Entrance:

Citrus canker—eradication proceeding.
Foulbrood of bees.
Phylloxera of grape.

Introductions of a Serious Nature which have Recently Become Important:

Termites.
European wasp, *Vespa germanica*, 1944.
White butterfly, *Pieris rapae*, 1930.
Green vegetable bug.
Citrus canker.
Hard wax scale.
Soft wax scale.
Redlegged earth mite.
Nasella tussock.

Examples of Recent Importations Checked by Quarantine Officials:

August-November, 1948, at Auckland.

1 package water hyacinth—prohibited. 7 plants from India brought in as passenger's luggage, no accompanying certificate and the owner stated "These plants were grown in my own garden. I did not obtain a certificate from the agricultural authorities but these plants and the soil are quite healthy". Each of the 7 plants was found to be infected with one or more serious diseases including citrus canker and some scale insects not usually found in New Zealand.

15 packages from Norfolk Island--brought in by passengers by air. No accompanying certificates of freedom from disease and all found infected with scale insects, some of which had not been recorded in New Zealand.

1 parcel grapevine cuttings—no certificate re phylloxera or downy mildew.

2 bags of kumaras from Tonga arrived as passenger's luggage.

THE NEED FOR OVERHAUL OF THE EXISTING PROCEDURE AND CERTAIN RECOMMENDATIONS

In making a review of the existing quarantine system it is apparent that the time has arrived for a complete review of plant quarantines in New Zealand, but in doing so one must realize the important work that has been done in the past, often with insufficient technical knowledge and general apathy or opposition from various sections of the community who regarded the measures adopted as irksome and unnecessary control. This problem should be tackled from the national and from the international point of view.

Here are some points for consideration:

1. No system of plant quarantine is completely watertight. This is more important today with the development of air travel for passengers and parcel post. Therefore plans must be laid beforehand to meet these new plant plagues whether fungus or insect, bacterium or virus. As soon as a new disease is identified a quick survey should be made of its extent. Then whilst still limited a definite attempt at eradication should be made in most instances. Inspectors should be available for these surveys and an adequate "fighting fund" always available for the Horticulture Division to use for eradication and compensation. There must be a greater realization in the community that eradication campaigns are a community effort for the benefit of society as a whole, whilst control measures must and should remain the responsibility of the individual. To spend weeks, months or years discussing compensation scales or legal regulations is fatal in a campaign of this nature.

2. All existing measures should be reviewed to see whether the reasons for their introduction still exist or whether additional knowledge makes a change necessary. The policy should be clear and definite so that law and practice correspond and the action required by an Inspector is clear cut. These are a few instances for review:

A. A complete embargo against all fruits from a country in which Mediterranean fruit fly exists is too rigid—literally it means no citrus fruits from the irrigation districts of New South Wales even if this fruit fly is only in the coastal districts. It means, too, no pineapples from Queensland even if there is no record of pineapples being attacked by the Mediterranean fruit fly.

B. A complete embargo is maintained against all apple, pear and quince trees from any country in which Fireblight exists when today Fireblight is recorded in every district in New Zealand. The Fireblight certificate that . . . came from a district in . . . which is free from Pearblight or Fireblight of the pear would still be a wise safeguard. Should not the complete embargo be rescinded? The present procedure is only justified if a complete eradication policy is being undertaken in New Zealand.

C. For certain vegetables of the family Cruciferae (cabbage, cauliflower, etc.) Australia requires a certificate that the white butterfly, *Pieris rapae,* does not exist in the part of the country where the vegetables were grown. It is doubtful whether there is such a district in New Zealand today. Does white butterfly exist in Australia? If not, an embargo on the Cruciferae is necessary. If it does exist, this prohibition requires reconsideration.

D. Annual certificates from Fiji, Cook Island or Norfolk Island that Mediterranean fruit fly does not exist there. Immediate notice would be necessary—exports should cease or this precaution is inadequate.

3. Although there must be a close liaison between import control—a function of Customs Department—there should be no confusion in the public mind and an attitude develop that "plant quarantine" is synonymous with a trade barrier. Cases for review are potatoes and fruit from New Zealand to Australia or the lifting of the prohibition against export of the seed of New Zealand flax, *Phormium tenax*.

4. With a remote country such as New Zealand the ports of entry should be reduced to a minimum, possibly only Auckland, Wellington, Lyttelton, Dunedin and Bluff and well equipped with modern fumigators, such as by vacuum process, and other treatment facilities installed at these points. All sub-ports and airports should be withdrawn as ports of entry.

Specialists as Port Horticultural Inspector should be stationed at these ports of entry. These inspectors should become efficient in recognizing diseases which are not recorded in New Zealand. They should have some opportunity to know Inspectors in neighbouring countries through inter-change of personnel and develop an international code in certification of plants as free from disease. Regular discussions on plant quarantine policy should also take place between the administrative officers.

5. The Schedules 12th, 13th, 14th and 15th in the regulations in regard to the importation of fruit or plants into New Zealand should be re-drafted with common name and scientific name today. The standard treatments recommended should be those of qualified entomologists and mycologists and all the diseases re-classified in their appropriate category.

6. Definite quarantine areas should be established remote from nurseries, orchards or commercial gardens and all new plant introductions, valuable plants without certificates, or where adequate fumigation or dipping cannot be done, should be planted out for a period of up to three years on the quarantine station. Quarantine as practised today on a producer's property is not true quarantine. The system today appears too dependent on certificates.

7. Only one of the three following certificates are required from a country exporting to New Zealand:

A. A nursery inspector's certificate.

B. Fumigation, dipping or spraying has been carried out.

C. Freedom from disease.

I question whether these certificates are of equal value and that treatment is necessary at point of export or import whether disease is visible or not. Of course there is need to be sure that treatment is adequate or quarantine will still be required.

These certificates should also cover "apparently sound" when inspected, as bulbs have been known to arrive rotten through having got wet and yet were free from disease.

8. A complete embargo on fruit and plants brought to New Zealand as passenger's luggage by air or sea needs consideration. Such

products should be used by passengers or dumped at sea outside territorial waters and passengers advised these products will be treated as contraband. Similar action would be necessary with naval vessels which at present arrive uninspected.

9. With New Zealand comprising two main distinct islands, is not a local quarantine necessary to keep wasps in the North and nassella tussock in the South? Such a practice has been in operation with grape vines and fruit trees from North to South Island.

Discussion

Miller (New Zealand) questioned the usefulness of certificates of freedom from termites where hardwood poles were not shipped immediately after inspection as re-infestation could occur if a long period elapsed before shipment. He also mentioned that there were records of the establishment, for a short period, of *Ceratitis capitata* in New Zealand.

Pemberton (Hawaii) stressed the desirability of having as few ports of entry as possible.

GENERAL

RELATIONSHIP BETWEEN INSECTS AND MUSHROOMS

By R. Heim, National Museum of Natural History, Paris

[*Translation*]

Unique formations are found near the queen cells in some termites' nests. They are plastic in form, resembling sponges or large nut-kernels, and are hollowed, furrowed, and fit fairly closely into the ramifications of the nest. This is made of a light homogeneous substance composed of wood waste, which is now known to be masticated and cemented by worker termites.

In 1770 König in India, and Smeathman in tropical Africa, discovered numerous small spongiform protuberances. These were globular, fleshy, and never more than 1-2 mm. in diameter, and looked like tiny mushrooms. These fungal growths were considered to be associated with the formations they resembled, the supports being named "combs" or mushroom gardens, while the little mushrooms were named "spheres".

For many years no connection was suspected between the tiny spheres discovered by König and the large Agarics growing on the termite mounds. Finally, in 1906 the eminent English mycologist Petch posed the problem squarely and foreshadowed its solution. Petch, of course, connects the problem with the discoveries of Bates and Thomas Belt on the *Atta* ants. These ants, now called "leaf-cutters", make combs with the aid of leaf detritus which they cut into tiny pieces. The opinion has long been held that they grow mushrooms on these for food. Petch, struck by their resemblance, assumed identity between the two forms. He conjectured purposeful cultivation in both cases, considering that the microscopic spheres he found on the combs of the termites' nests belonged to the mycelium of aerial Agarics.

I pass over the many papers published since then, especially by entomologists, on mushrooms in termites' nests, and the so-called cultivation performed by the insects. It has become the classic thesis, such is the seductive power of error!

I came to take up this investigation *ab initio* and the result of these researches has led me to the following conclusions:

1. The spheres are the subterranean embryos of the Agaric in the termites' nests.

We have furnished both embryological and cultural proofs of this. Firstly we followed the complete evolution of the Agaric in the termite nests among the several species, from the mycelium attached to the subterranean combs to the full development of the carpophore. The sphere should be taken anatomically as an embryo or immature state of the Agaric. The hymenium does not appear in small isolated spheres; but will only come out later when this sphere proliferates in the form of a nascent pseudorhize. This long fine thread will gradually pierce the hard cement of the termite nest over a distance beneath the ground of up to two metres. We still awaited the experimental proof: fortune favoured us. Starting with young spheres, collected deep down from subterranean combs built by *Pseudocanthotermes militaris* in Guinea, we managed to obtain cultures on artificial media of colonies formed from groups of tiny spheres, each group being homologous with a natural sphere. These artificial formations have the same structure as natural spheres similarly composed of spherocysts; or spherical cells bearing ovoid bi-nuclear yeast-like cells, each nucleus containing four chromosomes. Moreover, from the basidiospores of the Agaric we succeeded in directly reproducing, on a glucose peptone medium, artificial spheres identical with those we had already obtained.

2. A second problem, a very delicate one, remained to be cleared up. It was that of the systematic position of the Agarics in the termite nests.

The search after specificity in the Agarics is strewn with difficulties. Characteristics which we are accustomed to think of as fixed within a genus, turned out to be variable from species to species, even within the same form. There seemed sufficient evidence to place the Agarics in the termite nests together in one new genus which I have called *Termitomyces*. All the Agarics fastened to the combs of the inhabited termite nests are *Termitomyces*; and *Termitomyces* contains only termitophile species.

The insects feed on the spheres only incidentally. Petch's theory of weeding explains that the termite throws out the foreign *Xylaria* so as to retain only the Agaric, the sole cultivated species chosen. The following observations by Bathellier strengthen our doubts. At Saigon, Bathellier went to the extent of keeping in the open air, away from the termite nests, pieces of nests where *Macrotermes gilvus* had lived with their mushroom combs. These combs were the scene of an intense growth of *Xylaria*. And he observed that as soon as the proliferation of the *Xylaria* hindered the free movement of termites on top of the combs the workers pulled off the spheres of the other mushroom—the *Termitomyces*—and threw it out of the inhabited part. Naturally this action has no effect on the troublesome growth of *Xylaria*. Hence we deduce two hypotheses.

1. The termite seems incapable of distinguishing one from the other, which destroys the theory of weeding, and;

2. If it casts out the spheres it is because it has learnt this action. It repeats it unconsciously and unnecessarily, and is accustomed to doing it in the nest. I would thus explain why certain cells are full of divided spheres: they are not larders, they are "police cells". They are where the termites store the spheres when their growth becomes a nuisance, and where they can do no harm.

The Agaric is certainly an intruder. One is used to it, one lives with it, it is true. But on occasions one can quite well cast it out of the termite nest, which is the case with the famous *Mycena microcarpa*. The Agaric is thus an undesirable associate of the termite, the contrary of the classic theory. The comb is an essential feature in the structure of the nest, a refinement of that architecture in which the termite is a past master. But this surprising structure has its weakness; it is made of a substance which suits certain mushrooms, which grow on the substratum it provides. The *Termitomyces* are adapted to this environment. As for the termites, they have not a cultivating reaction to the mushrooms, but simply an occupational one. They are incessant workers, but their labour is not necessarily governed by a sense of output. Everything is subordinated to the need for work.

In this resume of work undertaken personally and already published elsewhere in French, my only intention has been to give a somewhat brief and unelaborated account, drawing attention, among other things, to the fact that *Termitomyces* until now have not been found except in intertropical Africa, India, Indonesia, Indo-China, and the Philippines. Neither Oceania, New Zealand, or Australia—despite the richness of their unusual termite fauna—nor Madagascar seem to contain *Macrotermitinae* linked with the growth and cultivation of termitophile Agarics.

SOME FEATURES OF THE DISTRIBUTION OF INSECT LIFE ON PHILIPPINE MOUNTAINS

By Leopoldo B. Uichanco, College of Agriculture, University of the Philippines

As a consequence of enemy action in the last world war, all the entomological collections, records and nearly all the library resources in the different scientific units in Manila and Los Baños were consumed by flames. Thus, all the specimens and data which I had tried to accumulate off and on for some ten years on the subject of vertical distribution of insects on Mt. Maquiling and other Philippine mountains were lost. With the co-operation of my associates and students in entomology in the College of Agriculture and the collectors of the Philippine National Museum, I have been trying to reassemble mountain specimens since resumption of work in 1945. Progress has been painfully slow, on account of meagre facilities and frequent interruption by more pressing duties. On the basis of the partially worked out new small collection, supplemented by such lost older data as I could reconstruct, I have attempted to prepare the present paper. Part of the identification is difficult to verify on account of lack of references.

To one whose familiarity with insect life in the Philippines is largely limited to the lowland forms, one remarkable feature that strikes his attention when he first ascends a couple of thousand metres on the mountain, such as the altitude of Baguio, Mountain Province, on the island of Luzon, is the fact that he encounters there quite a few very familiar lowland species alongside the characteristic mountain biota. Among the mountain flowers, he comes across familiar bees like *Apis indica* Fabricius (Apidae) and *Trigona biroi* Friese (Meliponidae), and such butterflies and moths as *Baoris mathias* Fabricius and *Astycus palmarum chrysozona* Plötz (Hesperiidae), *Lampides boeticus* (Lycaenidae), *Terias hecabe* Linnaeus (Pieridae), *Hymenia fascialis* (Cramer) (Pyraustidae), and *Utetheisa pulchelloides* (Arctiidae). Other outstanding insect examples that have a great vertical range are: *Collyris* (*Neocollyris*) *albitarsis* Erichson (Cicindelidae), which is a widely distributed species in the Philippines. Because of its aberrant habit as a twig borer, it causes serious damage to coffee and madre de cacao in the lowlands. The species has been recorded from Baguio (Schultze, 1915, p. 9).[1] In the plantation at Impalutao, Bukidnon province, Mindanao, it was reported as occasionally injurious on cinchona. *Chilomenes sex-maculata* Fabricius (Coccinellidae), predatory on aphids; *Nisotra gemella* Erichson (Halticidae), feeding on leaves of Malvaceae; *Aspidomorpha miliaris* Fabricius (Cassididae), on leaves of Convolvulaceae, *Laccoptera philippinensis* Blanchard, also on Convolvulaceae, and *Metriona trivittata* Fabricius, on Convolvulaceae and Amaranthaceae; *Epepeotes ambigenus* Chevrolat (Cerambycidae), on Moraceae; *Cetonia gregori* Moser (Centioniidae); and *Clyster itys* Oliver (Dynastidae); and *Dysdercus megalopygus* Breddin (Pyrrhocoridae), on Malvaceae, are species which appear to be at home at all elevations. *Gastrimargus mamoratus* Thunberg, a common grasshopper on the lowlands is also occasionally collected on the Mountain Province. From time to time in Baguio City, large swarms of adult mound-building termites, *Macrotermes gilvus* Hagen, are attracted to street lights. However, their mounds which are a common feature of the lowland landscape are conspicuous by their absence in the mountain capital. It is quite possible that the swarms were carried up from surrounding lowlands by ascending wind currents.

The common household cockroaches—*Leucophaea maderae* (Fabricius), *Pycnosceles surinamensis* (Linnaeus), *Blattina orientalis* Linnaeus, *Periplaneta americana* (Linnaeus), *Periplaneta australasiae* (Fabricius), and *Neostylopyga rhombifolia* (Stoll)—may be found in almost all elevations. The same is true with the bedbug, *Cimex rotundatus* Signoret, the two species of houseflies, *Musca vicina* Macquart and *Musca nebulo* Fabricius, and also with insects affecting stored food products. Fleas of undetermined species have at times been so abundant as to be a nuisance to dwellings in Haight's Place, on Mt. Pauai, at about 2,400 metres elevation. However, the common household ants, which can be very annoying in the lowlands, are blissfully rare or absent in the higher altitudes. Sweets left on the table in my hotel room in Baguio remained from day to day absolutely free from the swarm of ants which in the lower plains would have overwhelmed the food in a couple of hours.

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[1] Schulze, W., 1915. A catalogue of Philippine Coleoptera, 198 pp. Manila: Bureau of Science Pub. No. 7.

Malariologists are agreed that communities situated at an elevation of 600 metres and above are malaria-free. Although there are over two dozen known species of *Anopheles* in the Philippines, *A.* (*Myzomyia*) *minimus flavirostris* (Ludlow), which is the most important vector, does not occur at altitudes higher than 600 metres (Bohart, 1945, pp. 20-21).[2] *Anopheles* (*Anopheles*) *lindsaii benguetensis* King, which occurs in the Baguio area, apparently does not transmit human malaria.

With the exception of relatively few insect forms which exhibit a wide adaptive range in their vertical distribution, a large majority of the species appear to be more or less definitely stratified in their occurrence. A very characteristic form which seems to be restricted at or near the summit of Mt. Maquiling, on Luzon, at an elevation of 1,100 metres is the striking green staphylinid, *Hesperus phenomenalis* Bernhauer, which is abundant among the rattans in the mossy forest. The large syrphid fly, *Milesia semperi,* which startlingly simulates a bee, is another summit inhabitant. Pentatomids, such as *Taurodes boops, Hoplistosdera convexa, Zicrona caerulea* (Linnaeus), and *Spermatodes granum* Bergroth (feeding on *Solanum ferox* Linnaeus and said to be the smallest pentatomid in the world) are also strictly summit insects. The black wood-cockroach, *Panesthia javanica* Serville, lives in fallen tree trunks from the middle altitude to the summit. I have collected this species both on Mt. Maquiling and in the Mountain Province, at about 2,000 metres elevation. In the latter locality, at somewhat higher levels, is another characteristic species, *Panesthia ornata* De Saussure. The latter is very common on Haight's Place. The danaid butterfly, *Hestia leuconoë* Erichson, does not begin to be met with until one ascends to an elevation of about 300 metres on Mt. Maquiling. For two or three days after a typhoon strikes, an occasional typical higher altitude insect is collected at lower levels. Thus at times we capture on the campus of the College of Agriculture, at an elevation of 50 to 80 metres, such species as *Papilio xuthus, Papilio magellanus, Actias selene, Antherea semperi* Felder, and *Eupterote fabia,* which under normal conditions are only found higher up.

Bumblebees appear to represent part of a relic fauna which occurs only on or close to mountain tops, where they exhibit a high degree of endemism. They seem to replace in the higher elevations the carpenter bees of the lowland. Frison (1925, 1928)[3] published a convenient revision of all bumblebees known from the Philippines. I am enumerating below the three species and two varieties known from the Philippines, with the addition of supplementary records from our own collecting.

ENUMERATION OF PHILIPPINE BUMBLEBEES

Bremus (*Hortobombus*) *isisanensis* (Cockerell)
  Luzon, Nueva Vizcaya, Imugan, (Frison, 1928).
  Luzon, Mt. Province, Irisan, near Baguio, (Cockerell, 1919).

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[2] Bohart, Richard M., 1945. A synopsis of the Philippine mosquitoes, 88 pp. 10 pl., Washington: Department of the Navy, Bureau of Medicine and Surgery.

[3] Frison, Theodore H., 1925. The bumblebees of the Philippine Islands (Bremidae: Hymenoptera), *Philip. Journ. Sci.*, 27: 113-124, 1 pl.

Frison, Theodore H., 1928. The bumblebees of the Philippine Islands (Bremidae: Hymenoptera), *Philip. Journ. Sci.*, 37: 273-284, 1 pl.

Luzon, Mt. Province, Trinidad, elev. 1450 metres, April 28, 1931, (Uichanco, coll.). Frison det.

Bremus (*Pratobombus*) *baguionensis* (Cockerell)
Luzon, Mt. Province, Mt. Paoay, Haight's Place, elev. 2,400 metres.
(Cockerell, 1920, "Benguet, Baguio").
(Frison, 1925).
(Uichanco, coll., May 4, 1931). Frison det.

Bremus (*Pratobombus*) *baguionensis* var. *imuganensis* (Hedicke)
Luzon, Nueva Vizcaya, Imugan, (Hedicke, 1926).
Luzon, Mt. Banahao.
Kinabuhayan, elev. 500 metres, March 21, 1934 (Pangga, coll. 1 worker). Frison det.
Tatlong Tangke, elev. 1,000 metres, March 21, 1934 (Madrid, coll.). Frison det.
Elev. 1,200 metres (Williams, coll. [Frison, 1928]).
Elev. 1,600 metres, May 21, 1934 (Madrid, coll.). Frison det.
Near summit, elev. 2,000 m., May 21-23, 1933 (Madrid and Coronel, coll.). Frison det.

Bremus mearnsi (Ashmead)
Mindanao, Mt. Apo, elev. 1,800 metres (Cockerell, 1919; Frison, 1925).
Mindanao, Mt. Malindang, summit, elev. 2,425 metres (Frison, 1925).

Bremus mearnsi var. *bakeri* (Cockerell)
Negros, Cuernos Mountains (Cockerell, 1920; Frison, 1925).
Negros, Mt. Canlaon, elev. 1,524 metres (Frison, 1928).

In addition, there is the possibility of occurrence in the Mountain Province of a fourth species, *Bremus americanorum* (Fabricius), which was introduced here from the United States in 1909 "for the purpose of fertilizing clover". Hitherto, however, there has been no authentic record of recovery of this species.

The distribution of bumblebees on the island of Luzon is very interesting. In Imugan, Nueva Vizcaya, lat. 16° 10′ N. and long. 120° 55′ E., *Bremus irisanensis* and *B. baguionensis* var. *imuganensis* meet. *B. baguionensis* var. *baguionensis* is apparently confined to Haight's Place, on Mt. Pauai, lat. 16° 38′ N. and long. 120° 45′, to the exclusion of other forms. Again, *B. irisanensis* extends westward to Trinidad, lat. 16° 28′, long. 120° 35′, a distance of some 50 kilometres from Imugan over almost continuous elevated land; then about 30 kilometres southward to Irisan, lat. 16° 26′ N., long. 120° 33′ E., again over almost continuous highland. However, *B. baguionensis* var. *imuganensis,* for some reason, did not follow the westward extension of *B. irisanensis.* Instead, the former followed a southward or southeastward course, presumably along the eastern Cordillera of Luzon, and we meet it again on Mt. Banahao, lat. 14° 05′, long. 121° 30′, in southern Tayabas (now Quezon) province. Mt. Banahao, like Mt. Maquiling, lat. 14° 08′ N., long. 121° 12′ E., some 50 kilometres to its west, are extinct volcanoes which show no sign of recent eruptive activities. According to Adams (1910)[4] these two mountains are

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[4] Adams, George I., 1910. Geologic reconnaissance of south-western Luzon, *Philip. Journ. Sci.,* SA 5: 57-116, Pl. 1-13; Fig. 1 10; 2 maps.

"classified as within the tuff plains. They are neo-volcanic . . ." It is therefore probable that Mt. Banahao, on account of its youth, did not originally have any bumblebee in its fauna so that *B. baguionensis imuganensis* must have migrated there from the north, by way of the almost continuous high plateau separating this mountain from the eastern Cordillera of Luzon. No bumblebee is found on Mt. Maquiling because the intervening land consists of "tuff plains, their rims rising but a few metres above the general level of the country". (Adams, 1910).[4] But why *B. baguionensis imuganensis* succeeded in extending its range southward to Mt. Banahao from Imugan, while *B. irisanensis* did not; whereas the latter species spread westward to Trinidad and thence southward to Irisan, while the former species did not, constitutes an intriguing biological puzzle which does not lend itself to easy solution. The root causes are doubtless traceable to a complex set of factors, of which the most important may probably be grouped into three main categories: (1) geological history of the areas concerned; (2) present land topography of the areas concerned; and (3) biological peculiarities of the different Philippine species and varieties of *Bremus*. The possible Pleistocene geography of the Philippines is discussed by Dickerson *et al.* (1928)[5] and graphically illustrated in a map on p. 95 of their publication. The areas on which the various collection localities of *Bremus* on Luzon are situated formed part of a continuous Pleistocene island over which, in the cold climate alternately obtaining during parts of that epoch, bumble bees presumably had every opportunity to spread. *B. baguionensis* var. *baguionensis* may probably be a derelict form of the species, which was halted on what is now Mt. Pauai by some unknown barrier on its westward course of migration. The occurrence of *B. baguionensis* var. *imuganensis* on sitio Kinabuhayan, at an altitude of 500 metres on the northwestern slope of Mt. Banahao, perhaps connotes a higher temperature requirement (or tolerance) for the species than that of other forms of Philippine bumble bees, which have been found only at much higher elevations.

Pleistocene geography would probably also account for the simultaneous occurrence of *Bremus mearnsi* in Mindanao on Mt. Apo, lat. 7° 03′, long. 125° 17′, as well as on Mt. Malindang, lat. 8° 15′, long. 123° 35′, despite the wide gaps of intervening lowland areas. The occurrence of *Bremus mearnsi* var. *bakeri* on Mt. Canlaon, lat 10° 25′, long. 123° 6′, and Cuernos Mts., lat. 9° 15′, long. 123° 10′, on the island of Negros, almost due north from the portion of the Zamboanga Peninsula where Mt. Malindang is located and separated from it by a scant thirty nautical miles of sea, is probably traceable to a somewhat older geological history.

Another interesting group is represented by the cicadid genus *Psythirystria* Stal, which is endemic to the Philippines. Almost every high mountain apparently has its characteristic species, where it occurs at or near the summit. We had an extensive collection in this genus prior to the war, through combining the resources of the entomological laboratory of the College of Agriculture and that of the Bureau of Science. The various forms were determined readily, with the aid of the excellent descriptions and figures given by

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[5] Dickerson, Roy E., *et al.*, 1928. Distribution of life in the Philippines, 322 pp., illus., Manila: Bureau of Science Monograph 21.

Stal (1870)[6]. Although no new species was brought to light, the collection was valuable because the material gave precise locality records. (Stal had given only "Philippines" for his localities.) Unfortunately, our entire lot was destroyed. In May, 1948, Mr. M. Celestino, collector of the Philippine National Museum, brought down a fine series of specimens of *Psythirysiria* from the summit of Mt. Pulog. They represent two species, although I am unable to determine them at the present time because there is no longer a copy of Stal's work available to me. A curious habit of these small cicadas is the fact that they can be attracted in the daytime by the noise produced by repeatedly tapping the point of a hunting knife on tree trunk or successive clucking sounds with the mouth like that made by the groom driving his pony.

Another curious endemic group is that of the curculionid tribe Pachyrrhynchini, subfamily Brachyderinae. The genera *Pachyrrhynchus* Germar and *Metapocyrtus* Heller, of which all the individuals are entirely incapable of flight, are almost exclusively restricted to the Philippines and the various groups within the genera show a very high degree of local endemism within the Archipelago. In a published paper (Uichanco, 1940),[7] all the seven species recorded as pests of quinine seedlings in Bukidnon province, Mindanao, were highly endemic species, with their range confined to the Bukidnon area, or extending only to limited additional territories close by.

Although certain species of insects, such as *Bremus baguionensis* var. *imuganensis*, have spread southward to Mt. Banahao, a good number of species which are presumably Palaeartic derivatives (migrants?) appear to have stopped in their course at the Central Cordillera of Luzon, their range roughly co-extensive with the natural distribution of the Benguet pine, *Pinus insularis* Endlicher. Some conspicuous examples of insects with this restricted distribution in Luzon are the butterflies *Argynnis hyperbius* (Nymphalidae), *Vanessa* spp. (Nymphalidae), *Pieris canidia* Sparrman (Pieridae), *Precis orythia* Linnaeus (Pieridae), and the geometrid moth, *Milionia coronifera* Swinhoe. Since the opening of Baguio as the summer capital at the turn of the century and the growth of truck gardening in adjacent Trinidad Valley, *Pieris canidia* soon became an agricultural pest when cabbage was cultivated extensively. *Milionia coronifera* broke out in epidemic form around 1930, the larvae seriously defoliating the pines, which formed the dominant forest cover of the Baguio area.

It is difficult to evaluate the relative weights of the three principal factors as determinants of insect distribution—climate, food, and natural enemies. With respect to the first two, some cases might be cited that would tend to show the stronger influence of climate among insects which have relatively narrow adaptive ranges. Two common pests of *Pinus insularis* in the Mountain Province are a weevil, *Pachyrrhynchus pinorum* Pascoe, and an aphid, *Eulachnus pineti* (Koch). This pine can be grown readily in the lowlands, such as on the campus of the College of Agriculture, although in their new environment they do not reproduce. Neither of the two pest species have ever been found on this host on the College campus. Abaca, *Musa textilis* Née, has a serious pest in the lowlands all over the Philippines in the corm-weevil, *Cosmopolites sordidus* Germar, which, however, appears incapable of establishing itself when the host is grown at higher altitudes. In Bayabas, near Davao, Mindanao, about 500 metres on the slope of Mt. Apo, the important pest of abaca is not *Cosmopolites sordidus* but another weevil, *Odoiporus* sp., which attacks not only the corms but also the whole length of the pseudostem. The rice-stem borer of the lowlands is typically *Schoenobius incertellus* Walker; at higher elevations, *Chilo simplex* Butler. *Brithys crinum* Fabricius, which infests *Crinum zeylanicum* Linnaeus and related species when these are grown in Baguio, is replaced by another noctuid, *Calogramma festiva* Donovan, on the same hosts in the lowland. *Aleurocanthus spiniferus* Quaintance is a bad pest of the dogwood and rose in Baguio; on the low elevation of the College campus this insect has not occurred in any abundance, despite the fact that it finds plenty of host material in *Hibiscus*, rose, coconut, and *Citrus* species.

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[6] Stal, Carl, 1870. Hemiptera insularum philippinarum. Bidrag till philippinska öarnes Hemipter-fauna, *Ofv. Svenska Vet. Akad. Förh.*, 27: 607-776, Pl. 7-9 (707-776, Pl. 8-9).

[7] Uichanco, Leopoldo B., 1940. Insect defoliators on Cinchona in Mindanao, *Philip. Journ. Forestry*, 3: 45-49, Pl. 1.

A curious difference exists between Luzon and the more southern islands in the vertical distribution of insects. The case of *Precis orithya* Linnaeus, which in Luzon has been collected only at an elevation of about 2,000 metres, in the Baguio area, but which occurs at near sea level in Cebu and southern Mindanao, has already been the subject of an earlier report (Uichanco, 1938).[8] Other instances may be cited. *Anomala* (*Euchlora*) *inconsueta* Ohaus, which has been recorded in Luzon only from Baguio, also occurs in Calapan, Mindoro Island, near the seacoast (Schultze, *op. cit.*, 176). *Popillia cetrata* Newman is known in Luzon from Irisan only, near Baguio; the same species has been found in Bago, on the island of Negros, at a fairly low elevation (Schultze, *op. cit.* 178). *Stephanopholis philippinensis* Brenske is likewise found in Luzon in Baguio only; in the sugar cane fields of Negros Island, at the rather low elevations of Bago and La Carlota, this species is quite common and its larvae are among the more important white grubs affecting that crop. *Stenozygum bicolor* was collected from Tupi, in Mindanao, at about 50 metres elevation; in Luzon I have not come across it except from the middle altitude to the summit of Mt. Maquiling. It is quite probable that, in the more southern Philippine latitudes, important among the climatic factors that make for a wide distribution of those insect species which in Luzon are normally only high-mountain forms, is the higher atmospheric humidity, more copious rainfall or more uniform annual distribution of rainfall, greater cloudiness, and lower extreme ranges of temperature maxima.

SUMMARY

Except for a relatively few insect species which are at home in high mountain elevations as well as in the plains, most of the Philippine forms are more or less restricted in their vertical range. A number of high-mountain species exhibit strong local endemism, some developing into pests of economic crops as a consequence of agricultural exploitation of their native haunts. Peculiarities of distribution are explained on the basis of geological history and specific biological

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[8] Uichanco, Leopoldo B., 1939. Experience with a raised coral reef as hunting ground for butterflies in Mindanao, Philippines. *Verhandl. VII. Internat. Kong. für Entomologie*, 1: 437-443, 1 pl, Weimar: Druck von G. Uschmann.

characteristics. Evidence is adduced which tends to indicate the greater relative weight of climatic factors as against availability of food in determining establishment of species in new territory. That normally high-mountain insect species in Luzon are encountered at near sea level in the more southern Philippine latitudes is explained on the basis of differences in such physical environmental factors as atmospheric humidity, cloudiness, quantity and annual distribution of rainfall and ranges of temperature maxima.

Discussion

O'Connor (Fiji) commented on the distribution of *Anopheles* at high altitudes in New Guinea, and Dumbleton (New Zealand) on the local distribution and apparently varying ecological requirements of bumblebees.

ACTIVITE SAISONNIERE DE LA FAUNE ECONOMIQUE NEO-CALEDONIENNE

Par F. Cohic, Institut Français d'Océanie, Noumea

Dans cette modeste contribution nous nous sommes efforcés de mettre en relief l'incidence climatique sur les processus évolutifs et phénologiques de la faune économique et de définir dans un but pratique les différentes modalités de la variation saisonnière.

Nos recherches nous ont amenés à distinguer trois types bien tranchés d'activité:

- un maximum en saison fraîche et sêche;
- un maximum en saison humide et chaude;
- deux maxima, l'un en saison humide, l'autre en saison sêche.

A — Chez la majorité des coccides on note une période de latence purement trophique durant la saison des pluies, les phénomènes de séxualité ne se déclenchant activement qu'à partir de Mai-Juin dêbut de la saison sêche. Ce fut le cas de *Chrysomphalus aonidum* L., *Hemichionaspis* sp., *Lepidosaphes beckii* Newm. Au sujet de cette dernière diaspine il est interessant de citer la rupture d'équilibre observée dans la symbiose *Septobasidium bogoriense-Lepidosaphes*. L'entomophyte a un développement plus net en saison estivale. Ce fut également le cas de *Fusarium juruanum* autre coccidophyte. Ce même type d'activité se trouve réalisé chez la plupart des Aphides, *Riptortus annulicornis* Boisd., *Sceliodes cordalis* Dbld., *Phyllotreta australis* Blackb., tous parasites sérieux des cultures.

B — Un autre type également unimodal, mais à maximum estival est celui de l'*Othreis fullonia* Cl., Ophiderinae nuisible aux aurantiacées et indirectement au Caféier, les chenilles vivant sur *Erythrina fusca* qu'elles défolient parfois entièrement, à une période où le Caféier demande le plus d'ombrage. A ce type se rattachent de nombreux parasites et la plupart des Nematoceres Culicidae.

C. — La majorité des insectes appartiennent à un type d'activité bimodal. Le cas le plus marquant est celui de *Papilio amyntor* Boisd. A ce sujet nous notons une grosse variation de la durée du stade nymphal suivant la saison et une variation de taille très nette.

Orthorrhinus leselenci Jek (Goyavier), *Leptoglossus australis* F. (Cucurbitacées) et *Myctis profana* F. sont de ce groupe. Les générations de cette dernière espèce (saison sêche) se portent sur l'Aubergine, celle de saison humide sur Aurantiacées.

En conclusion, ceci nous amène à considérer différentes périodes écologiques en nous basant sur les critères évolutifs de la Flore et de la Faune d'une manière générale.

THE ESTABLISHMENT AND SPREAD IN NEW ZEALAND OF THE WASP *VESPA GERMANICA*

By C. R. Paterson, New Zealand Department of Agriculture

In April of 1945 several beekeepers living in close proximity to Hamilton noticed strange insects flying around their bee hives and honey houses. Several were caught and brought into Hamilton for identification. Synchronizing with this event came a telephone message to the office of the Department of Agriculture to the effect that bright yellow insects could be seen flying in and out of a hole in a clay bank. This was in the Rotokauri district, only about seven miles from Hamilton. Specimens were caught and compared with those collected by the beekeepers and appeared to be identical. Several residents, who still retained memories of school boy days in England, volunteered the information that the insects looked very much like the wasps so common over the English countryside. Specimens and pieces of the nest were forwarded to the Plant Diseases Division, Department of Scientific and Industrial Research, Auckland, for definite identification. Dr. Cottier in his reply stated that the insects were wasps of the species *Vespa germanica*. This identification was later confirmed by the Imperial Institute of Entomology, London. It was indicated that their discovery and establishment round Hamilton should be treated seriously for the following reasons:

1. Wasps are potential carriers of pathogenic organisms to our food.
2. Wasps foul food and annoy by their presence, especially if in numbers.
3. Accidents due to severe stinging.
4. Wasps are raiders of bee hives.
5. Wasps are destroyers of useful insects.
6. Wasps are destroyers of fruit.

Public interest was immediately aroused, and local newspapers stressed the necessity of treating the matter seriously.

Following this press propaganda the Department of Agriculture began to receive information of the discovery of other nests. The method of dealing with these first few nests was to apply calcium cyanide in the entrance and when all flying wasps had been overcome by the gas, to dig the nest out.

Unfortunately lack of knowledge resulted in the first two nests dealt with being so badly damaged that they were of little use as exhibits. The next nest, however, was secured intact, and served as a very useful and valuable specimen for lectures to the public and schools in the district. Seven nests were actually destroyed in the first year of their discovery in the Hamilton district. It was thought at the time that this may have accounted for all of them, and the wasp exterminated the first year of its discovery. Experience over the last few years has shown how little was actually known on the subject at that time. When the seven nests were discovered they were fully developed and had produced large numbers of queens which had already left the nest. Many of these had mated and gone into hibernation, so that actually the destruction of the nests had practically no controlling influence at all. To have been effective, the nests should have been discovered earlier and destruction carried out before production of queens had commenced.

The general public, although not unduly concerned about the establishment of *Vespa germanica* in the district, did offer many suggestions as to how it came into the country. On analysing the position it did appear rather strange that this species of wasps had not become established in New Zealand before this. It has been known in European countries and part of North America for many years. Aeroplanes coming over from the Pacific were blamed, and this appeared quite feasible, because large numbers of planes landed at the Rukuhia airfield. However, it was learned that this particular species was not to be found in any of the islands visited by our planes. Coastal areas adjacent to main shipping parts would have been the most likely places to find the initial establishment of this wasp. As Hamilton is situated well inland it would appear that an odd queen wasp must have come to the district in air force equipment. Hamilton at that time was the main repair depot and large quantities of packed equipment was stored there. Much of this would come by air transport from countries that are known to have *Vespa germanica.*

After the destruction of the seven nests in 1945, nothing further was heard or seen of wasps until the early spring of 1946, when our Department was notified that a queen wasp had been caught. This was sufficient warning of what was likely to happen later. The public were notified to keep a close look out for nests and all discovered would be destroyed by the Department. In February reports began to come in of nests being found all over the Hamilton area. These were dealt with by using calcium cyanide, and then digging out the nest and destroying by fire. After a number had been dealt with in this manner it was found that the officer carrying out the work of destruction was being seriously affected by the gas. Other means of destruction were then investigated. The following gives an indication of the extent of this work. I would like to mention at this juncture that during the season 1946 when 140 nests had to be dealt with, the Waikato was suffering from a very dry spell, and because of the peaty nature of much of the country any methods using fire had to be carefully avoided. This was rather unfortunate because the public offered some rather startling methods. One was the use of a plug of gelignite placed in the opening to the nest. This was most effective, but a method that could not be recommended for general use. Petrol poured into the opening and then ignited gave satisfactory results, but here again the danger to the operator was too great. The blow torch and spraying of fuel oil into the opening were also tried.

Experiments with many chemicals suggested by our Research Officer, Wallaceville Animal Research Station, gave varying results. After thoroughly testing the following: Calcium Cyanide, Derris Dust, Gammexane, Gammexane Bombs, 5 per cent DDT, liquid and powder

Chlordane, 10 per cent DDT, it was finally decided that 10 per cent DDT powder would be the most satisfactory to use since it was procurable in large quantities, and at a reasonable price. It was also comparatively safe for handling by the general public, and when applied correctly gave definite results.

With the problem solved of effectively dealing with located nests, a problem of much greater concern became evident. This was the rapid increase of these wasps in spite of the fact that all reported nests had been destroyed. In 1945, the year when *Vespa germanica* was first discovered, seven nests were destroyed; 1946, 140; 1947, 450; while in 1948 over 3,000 were accounted for. These figures clearly indicate the rapid increase of the wasp over a very short period in spite of the active measures taken to control it. If this rapid wasp increase could have been kept in the Waikato it would have become a local problem. Unfortunately this is not the case, and their rapid spread is causing concern to the general public all over New Zealand. In four years the wasps have spread out from Hamilton in all directions, and now cover almost half of the North Island.

The public reaction after the first announcement that a new pest had become established was that of indifference. Many considered that the wasp would be valuable in controlling flies, and even perhaps the white butterfly. After four years' experience of the insect in the Waikato, all are now of the opinion that they would rather have the flies than wasps.

During the short period of establishment in the Waikato it became evident that the wasp had an environment most favourable to its rapid increase. In 1947 many of what appeared to be newly developed nests were destroyed late into May and early June (early winter). It was considered that these must have been started by queens produced from early nests the same season. Last season worker wasps were to be seen flying around during the winter and early spring. Several of these over-wintered nests were dealt with in October. Queens and drones were actually seen mating at that time. It is quite evident that the wasp has already modified its life cycle to our favourable climate, and it is possible that active nests will be in existence all the year round.

The Department of Agriculture, therefore, decided on a comprehensive Wasp Control Campaign, in a determined effort to check this pest. It was realized that a considerable amount of research would be necessary to discover the best means of control. As this was looked on as possibly a long term programme some active measures had to be devised for an immediate control. The campaign was, therefore, divided into three groups.

1. *Research.* This was placed in charge of an officer of the Animal Research Station, Wallaceville. Investigations were to be carried out dealing with the possibility of discovering some attractant, meat or chemical, that could be used for trapping queen wasps, and later for worker wasps. The possibility of using lures for hibernating queens is still to be investigated. The Plant Diseases Division, Department of Scientific and Industrial Research, Auckland, has undertaken to check up on the biology of the wasp, and the possibility of parasitical control.

Entomologists who have just returned from visiting England and other countries were asked to gather all the latest information possible. At the time of drawing up the control programme it was impossible to speculate as to how long it would take before results could be expected.

It may be of interest to learn that results to date are very encouraging as it has been discovered that the queen wasps during spring and early summer have been keenly attracted to certain trees which are covered in honey dew. The spraying of these with DDT may mean the killing off of large numbers of queens prior to and just after nests have been commenced.

2. *Publicity.* This was something that could be undertaken immediately, and the fullest information passed on to the public. It was realized right from when the wasps were first discovered in Hamilton that it was a problem that needed the fullest co-operation from everyone. Large numbers of pamphlets were distributed to schools and public bodies indicating the alarming increase and spread of the wasps. A full description of the life cycle of *Vespa germanica* was given so that everyone could appreciate the problems of control and the early recognition of the wasp in new areas. Simple methods of destroying nests were given with a free issue of DDT powder. Agriculture and Pastoral Shows were made use of for displaying exhibits of nests and methods of destruction. All officers of the Department of Agriculture were fully informed of the control campaign and were instructed to assist in every way possible, especially in giving information to the public as to identification, location of nests and their destruction. Mounted specimens were distributed to local bodies and our own officers who had not yet encountered the wasp. Press publicity was exploited to the fullest, while several radio talks were given over various stations.

3. *Field Work.* The destruction of nests by Departmental officers was costing between three and four shillings per nest. It was, therefore, decided to try and get the queens before nests were established. In the first week of August of last year it was announced that a bounty of threepence would be paid on all queen wasps of the species *Vespa germanica* delivered or posted into the Department at Hamilton. Publicity was given as to the most likely places to look for queens, and in a very short time it became evident that a large number must have escaped destruction the previous season.

A great real of work was entailed in sorting and counting before the bounty could be paid out. Packets came in by the post, while many were delivered at the office. The numbers varied from a dozen or so to lots of 800. At one period queens were coming in at the rate of several thousands a day.

A schoolboy collected 2,400 in less than a week, and his total for the campaign amounted to 5,600. Underneath sacks and beneath bark of some rotted trees appeared to be where most of the queens were collected.

The payment of the bounty definitely ceased on 31st December. The number of queens collected totalled 118,251, with a payment in bounty of £1,478/2/9. A survey of queens sent in revealed that most of them had come in from an area of about a twenty mile radius from Hamilton. The wasps in other parts of the infected areas have evidently not reached sufficient strength for queens to be readily caught in hibernating places.

If numbers mean anything, then we have had a very successful wasp season in the Waikato. At the present time it is yet too early to tell if any beneficial results can be attributed to this means of control. It is doubtful if a bounty on queens could be carried out for another season, as it is feared that many nests this autumn would be farmed.

Already fifty nests have been dealt with this season, and the Department is at present sending out supplies of DDT packed in 2 oz. tins to Borough and County Councils. Where people are unable to deal with the nest themselves arrangements have been made to have part-time men available in each district to deal with these nests.

An endeavour is now being made to get as many nests as possible destroyed before queen production begins. Unfortunately it appears as if nests are not easily located until almost fully developed. Already nests have been destroyed near Whakatane on the east coast and as far south as Taumarunui. The next few months will, no doubt, show fresh areas infested as it appears hopeless to control the spread of the wasp. It will also show if the control measures already carried out are making any appreciable reduction in the incidence of wasps in the Waikato. It now rests with the public to diligently search for and destroy all nests.

Discussion

In reply to Dumbleton (New Zealand) it was stated that animal deaths due to wasp stings were recorded in New Zealand for horse and dog, that apples and grapes were damaged and that robbing of weak honeybee colonies occurred.

INSECT AND RODENT CONTROL METHODS IN THE FAR EAST COMMAND, U.S. ARMY

By Austin W. Morrill, Jr., Engineer Sections, G.H.Q., S.C.A.P.

At the close of the war in the Pacific, insect and rodent control fell into a condition of some disorganization due to the rapid return of trained personnel to the United States and the impossibility of setting up normal peacetime operations so quickly. Equipment, some of it obsolete in design, consisted of combat left-overs which had suffered such hard usage or unprotected storage that it was often nearly useless.

Under these conditions heavy reliance was being placed on airplane spraying. Large quantities of DDT in diesel oil were being distributed over the upper air and over roof tops by cargo planes. Unfortunately virtually all the persons acquainted with airplane spray requirements had left and spraying was done chiefly over buildings and habitated areas at midday and with widely diverse and dispersed patterns of application. The psychological effect, moreover, was such as to discourage personal protective measures or ground operations despite the fact that careful counts showed no diminution of adult mosquito populations.

In the Philippines the chief malaria vector is *Anopheles minimus* var. *flavirostris* (which breeds in slowly flowing, partially vegetated streams). In Okinawa it is *A. hyrcanus sinensis*, though *A. minimus* occurs in the Southern Ryukyus, and in Japan the vector is chiefly *sinensis,* a rice-paddy breeder. In addition to malaria vectors, however, there was, and is, an abundance of "pest" mosquitoes some of which are implicated in the transmission of other diseases. Such commonly distributed species as *Aedes aegypti* and *Aedes albopictus,* the dengue fever vectors, and *Culex quinquefasciatus (fatigans),* and *Culex tritaeniorhynchus,* the vectors of Japanese "B" encephalitis, found abundantly increased breeding areas in the hundreds of thousands of oil drums and emergency gas tanks and similar containers used for water storage in the shanties built by the war-made homeless, in the broken sewers, demolished catch basins and ruined concrete buildings. Newly re-established rice-paddies gave encouragement to *A. sinensis* and *Culex tritaeniorhynchus,* whose predatory enemies, perhaps because of indiscriminate and heavy airplane sprays, were very slow to catch up with them. Malaria and encephalitis occurrence were sharply up among the civil populations living in areas not under direct Army supervision but surrounding the small and widely scattered Army installations. All of these species, even including *A. minimus,* were found breeding in tin cans and abandoned equipment which Army personnel strew far and wide and which gave excellent protection both from airplane spraying and even from ground control.

During the war, populations of *Chrysomyia megacephala* and other flesh flies increased greatly and their control became a major problem in almost every area. These flies breed not only in dead flesh but also in latrines and exposed human waste; unlike the other common latrine-breeding fly, *Hermetia illucens, Chrysomyia* frequents mess halls and lights freely on food. Because of laxity or necessity, ideal breeding conditions for these flies remained long after combat was over. The control measures applied were negligibly effective although good results were reported to have been obtained with paradichlorobenzene in certain places. Dysentery frequencies were high.

As another concomitant of combat, rat populations reached new high levels. Ideal breeding areas abounded in destroyed buildings and other rubble. Storage of foodstuffs was far from rat proof and inability to harvest some foodstuffs in proper time, as in the case of coconuts on Guam and Luzon or rice in Okinawa, further encouraged rat increase.

All these problems were further complicated by the fact that the abnormal and increased breeding areas often contained land mines or unexploded grenades, bombs and ammunition; the absence of trained personnel to do either survey or control made habitat control become practicable only very slowly and initial programmes were chiefly attempts to sweep back the ocean. Control measures by individual units failed completely to cope with the situation.

In 1946 and 1947 a programme was instituted which provided trained enlisted and civilian personnel on a permanent and centralized basis. In the Philippines, Philippine Scout units of the United States Army were used for survey teams and Filipino civilian employees were trained as Entomological aides, technicians and crews. In Okinawa, Scout detachments were used for survey teams, Filipino technicians were employed to supervise and Okinawan men were employed as crews, while in Guam, both supervisory and crew personnel were brought from Manila. In Japan and Korea local civilians were employed as crews and American continental enlisted men were used for supervisors.

Persons having previous academic training or practical experience were chosen wherever possible. A very determined effort was made to employ the same persons permanently in order to assure continuity, to maintain interest and to develop leadership for future supervisory positions among the Japanese and Okinawans. This training programme was highly successful and many capable men have developed. Regular reviews and constant training of new people are being carried on as a basic part of the programme.

Control programmes as now set up comprise personal protective measures, interior control, rat and insect proofing of buildings and environmental control. Personal protective measures are urged by educative devices and required by regulation to insulate the individual from insects and to avoid disease transmission by the occasional insects which may penetrate our defences. These measures are such as use of repellants, a highly effective but slightly troublesome protection, use of nets and screens and care in avoiding the creation of breeding areas. While these measures are not the concern of the Engineer, they assist in the effectiveness of the programme and Engineer personnel are therefore used as demonstration agents and evangelists among their acquaintances.

Interior control of insects relies heavily upon DDT used as a residual. Oil sprays containing 5 per cent DDT and dusts containing 10 per cent DDT have produced relatively complete freedom from roaches, ants, bedbugs, fleas, mites, lice, flies and mosquitoes. Benzene hexachloride has been perhaps a bit more effective against roaches than DDT but proved to have so unpleasant and persistent an odour as to be useless in control of household insects.

In many areas rat or insect-proofing is not very feasible or sometimes even possible at all. However, proper attention to the habits of the pests concerned has shown that a little thought will enable barrier attempts to be surprisingly effective. Sprays which are applied to the places where flies, mosquitoes and other insects rest by preference will be vastly more effective than those applied perhaps more heavily but less discriminatingly. ANTU (alpha naphthylthiourea) dusted on regularly frequented rat runs and DDT dusted around stocks of flour and rice to act as a barrier to crawling storage insects have both produced results comparable to expensive and impracticable fumigation or restorage programmes.

Environmental control has encompassed both larval control and adult control. The former is by far the most important and has therefore been given the most attention. For stream breeding species of mosquitoes, control has consisted of applying DDT in diesel oil or operating siphon or lift-gate dams. No more clearing is done than absolutely necessary to enter and apply the oil since the lightest fog of material will penetrate to and poison the water for the larvae while leaving it safe for fish. Siphon dams are self-flushing dams which periodically pour a gush of water downstream, washing larvae out onto the bank or down the stream course. Lift-gate dams do the same thing manually. In both cases clean stream banks are desirable. In the Philippines, the malaria vector returns to the breeding areas for daytime resting and allowing a fog of spray to drift over bushes and grasses materially reduces the adult population.

Other types of fogs and fine mists produced by various so-called aerosol generators have been used. Some of these are attached to the exhaust of vehicles while others are provided with fire chambers and exhaust motors. In all cases, tests of populations showed good knockdown of flying adults but little overall effect on the population. No larval control by aerosols could be demonstrated. On the other hand, airplane-distributed dusts and sprays were quite effective against both larvae and adults where small, low-flying planes were used and areas were not too thickly vegetated.

DDT dust applied so as to drift in heavy clouds into paddies and streams gave good larval control and when dusted into shrubs and vegetation caused considerable reduction of adult populations. Four heavy applications at one week intervals resulted in such reduction of larvae that operations could be suspended until larval survey of individual areas indicated the need for "spot" re-treatments. In some cases this was as long as one month. Dusting of adult harbourages was continued at weekly intervals. Where animal-baited traps were available, populations of adult mosquitoes were found to diminish, and unsubstantiated observations in other areas seemed to confirm this.

Although adult fly breeding was considerable in areas closely contiguous to Army mess halls, and despite the fact that screens and walls were frequently far from complete obstructions to the ingress of the flies, the residual treatments proved sufficient to keep flies out of food dispensaries almost completely.

Use of DDT mists and dusts in surrounding vegetation was useful; treatment of exterior walls, particularly under eaves and in similar places where flies seek shelter at night and during rains, proved to be even more useful. This applying a DDT residual to places where flies appear to like to congregate was apparently the foundation stone of fly control since screens were propped open or knocked off almost universally and controlling all breeding on and even around the Post could hardly have reduced the area population to the required minimum. Where control operations were possible in fly breeding areas, dust and oil applications to manure compost and faecal sump pits gave a good reduction of emerging adults.

In addition to the control of disease, the control of shrub and tree feeding insects is a problem for the Army. During the control dusting of rice paddies, a light dusting of DDT at the rate of 4 pounds per acre was applied to several nearby fields of cabbages, sweet potatoes, tobacco and tomatoes in the Ryukyus. Four such applications gave good control of *Epitrix* flea beetles, *Diabrotica* spp., *Picris*, etc., and visibly greatly improved the quality and quantity of the yield. Similar treatments of vegetable gardens in the Philippines gave control of these and other plant feeders such as Lygeids, Pentatomids and aphis. Scale insects, mealy bugs and bag worms on trees and shrubs were controlled by two or even one application of DDT-Xylene emulsion concentrate diluted to 5 per cent. Where trees or shrubs were succulent, however, dilution was made to 2 per cent and applications were increased to three or four at weekly intervals. Control of the ants carrying these insects was secured at the same time and by subsequent applications of dust at infrequent intervals.

Termites occur in abundance in some of the Far East Command areas and are present in all areas. The use of 5 per cent DDT solution in diesel oil to saturate the ground was an effective control when applied at the standard rate of about four litres per one and one-half linear metres of foundation. Surface applications to ratan, bamboo and soft wood flooring and panelling of a similar solution in kerosene, gave control of *Dinoderus* wood-borers (principally *D. minutus*). Termite control by means of application of 10 per cent DDT dust to the interior of the mud shelter tubes was also attempted where soil access was difficult and was found to work very well. One such application gave control. Termite hills, where they were a nuisance because of obstruction or unsightliness, were also depopulated by introducing DDT dust after which the hills were levelled off and rebuilding did not recur. Chlordane and the customary Paris green were used similarly.

Observations on nearly all of these control measures were necessarily more pragmatic than strictly scientific. Nevertheless, on the basis of the Washingtonian doctrine that the end proves (or tests) the worthiness of the means, the results obtained seem to give a useful forwarding to our knowledge of insect and rodent control.

Discussion

Dumbleton (New Zealand) and Van Steenburg (Canada) discussed the efficacy and technique of airplane spraying.

Pletsch (U.S.A.) and O'Connor (Fiji) commented on the effect of such spraying in migratory species of mosquitoes such as *Aedes vigilax* in New Caledonia and the effect of such spraying on adult mosquitoes.

PACIFIC AREAS AND THE BIOLOGICAL CONTROL OF AGRICULTURAL PESTS

By Paul Vayssiere, National Museum of Natural History, Paris

[*Translation*]

From 5th to 7th August, 1948, conversations were held at Stockholm with the object of "organizing biological control on an international scale".

The initiative taken by the U.I.S.B. in arranging for this exchange of views arose from the fact that periodically the Bureau of Entomology in the United States and the Commonwealth Institute of Entomology in Great Britain held meetings of their respective specialists in biological control, in order to co-ordinate the results achieved and to establish a programme for future researches. From time to time, also, these two large organizations held joint meetings, such as that of 25th and 26th June, 1936, on the occasion of the inauguration of the laboratories at Belleville (Ontario). On the other hand, never, so far as we know, were the entomologists of other nations invited to take part in such discussions, which are of great importance, as much from the biological as from the economic point of view.

Moreover, most European countries, after the terrible experiences they have undergone, are now no longer able to plan the establishment of national organizations for exploiting the advantages of biological control. Without doubt this is the best and most economical means of protecting crops, but in addition it calls for the provision of fairly large sums of money, redeemable, it is true, but not the kind of advance which private financiers care to make in these days.

One possible solution remained: to tackle the problem on the international scale. The Stockholm meeting was absolutely conclusive on this point. The specialists present unanimously agreed on this principle, emphasizing, moreover, its value in relation to world peace.

European entomologists were particularly happy that three most eminent specialists, Drs. Nicholson and Wilson of Australia, and Dr. D. Miller of New Zealand, had agreed to give them the benefit of their wide experience in matters of the kind.

Today it must be admitted that these problems have outrun the imperial, and *a fortiori* the national, scale. It appears to us that the Seventh Pacific International Science Congress is peculiarly well qualified to express an opinion on this subject, and, if it thinks fit, to give the weight of its judgment to recommendations for the creation of an international organization for biological control.

I think there is no necessity to dwell at length either on the importance of such an organization or on the considerable part which must be played in any such organization by the lands whose shores are washed by the Pacific. The U.I.S.B. delegates, Professor R. Heim, and, especially, Dr. David Miller, the eminent specialist in biological control, will certainly be able to supplement appropriately this brief outline. I must, however, recall that on 10th August, 1948, the Economic and Social Council of United Nations, at its Geneva meeting, resolved to establish international research laboratories. It appeared to U.I.S.B. that the organization projected in terms of the Stockholm Conversations corresponded exactly in its objects to the international proposals of the Economic and Social Council, and U.I.S.B. therefore approached UNESCO and the Council with a request for their support in order to give effect to the proposal as early as possible. A recommendation from the Seventh Pacific International Science Congress, if it is in agreement with the conclusions reached at Stockholm, would be of great assistance to the realization of the project.

Discussion

Professor Heim (France) communicated the above proposal by Dr. Vayssiére for an international organization dealing with the biological control of insects.

Miller (New Zealand) who had been present at a meeting in Stockholm at the International Congress of Zoology, 1948, amplified and commented on the proposal.

Wang (UNESCO) said that UNESCO had resolved to convene a meeting of workers in this field to discuss the proposal.

Van Steenburg (Canada) said his Government, which was working in this field, had no official intimation of the proposals.

Wilson (Australia) stressed that interested Governments must be consulted before any binding action could be taken.

Pemberton (Hawaii) and Smith (California) suggested that no action could be taken and it was moved by Wilson (Australia) that while the meeting was in general sympathy with the ideals prompting Dr. Vayssiére's proposal no recommendation could be made by the meeting except that Dr. Vayssiére should endeavour to assemble the interested parties to discuss the matter further. This was seconded by Smith (California) and carried.

DIVISIONAL DISCUSSION ON WHALING IN THE PACIFIC

WHALING IN THE NORTH PACIFIC

UNDER the above title Dr. Carl L. Hubbs dealt mainly with the 30 to 50 ft. grey whale which migrates down the west coast of America from the Bering Sea, hitting the coast about the position of the Scripps Institution of Oceanography at La Jolla from mid-December to mid-February, then proceeding down the fringe of the coastal seaweed belt to certain lagoons in Lower California, where breeding takes place. The females go inside the lagoons, the males remaining outside, with mating taking place just within or just outside the mouths of the lagoons; gestation is little less than one year. For some years protected, owing to depletion, the number of grey whales is probably not as low as at first feared, being now estimated at about 2,500. Many of the observations on the whales were made by means of helicopters.—Ed.

DISCUSSION

Dr. R. C. Miller wished to know to what extent the killer whale was the enemy of the grey whale. Dr. Hubbs replied that the killer very definitely attacked the grey whale. He had watched chases along the coasts of California and had observed the killers to come into the lagoons after the grey calves. The cow was then observed to slip dexterously under the calf and raise it up by the flipper on the opposite side for protection. The number of grey whales killed by the killer whale was probably small. The grey whale does not spout when chased, but exhales deep beneath the water. Dr. Hubbs went on to describe the chase as a very dramatic sight. The killer and the grey whale recognized each other as much as half or three-quarters of a mile away, probably by sound. It should further be possible to tally by sounding methods such whales as pass the station by night.

Dr. Murphy commented that Dr. Hubbs had acquired a wealth of data as to the natural history of the grey whale which time had prevented being told in this discussion. Quite new to him was the evidence of Pleistocene or Recent grey whale remains encountered in the draining of the Zuider Zee on the Dutch coast.

Dr. Deacon also commented that the methods of aerial reconnaissance of whales and other improved technique described by Dr. Hubbs were of the greatest interest and importance. Dr. Foerster asked whether experiments had been done in the tagging or marking of grey whales. The difficulty in this field, it was answered, was that at present there was no recovery by fishing methods of whales so marked. Banners or flags had at times been affixed to passing whales, giving a speed estimate of 3 to 5 knots. It might be possible to stick in darts by a close-up approach of the helicopter. It would then be possible to see what percentage (females only) of tagged whales were present in the lagoon. Dr. Murphy suggested the use of the types of disc employed by the "Discovery", marking the whales against the future whaling operations of perhaps 25 - 30 years hence. Of the humpback and the right whales, the numbers were huge. Compared with these vast populations the numbers of grey whales seemed still very small.

Dr. Hubbs stated that the calves were exclusively confined to these lagoons, and that the estimated number of the whole population might be high. Dr. Deacon enquired whether there was any further information of the time spent under water or the depth attained. It might be possible to affix self-releasing pressure recorders to measure depth. The mode of swimming was described as primarily with the use of the flukes, with a slow, very flexible rhythmic movement of the body, both laterally and vertically. A 12 knots maximum cruising speed was mentioned.

Mr. McCann enquired about the migrations of the males. It was pointed out that the whole population come down the coast in middle December to February, but that the males stay outside at the bar, while the females enter the lagoon. Copulation had been observed only once (by Hilary), one bull mating successively with two females accompanied by calves.

Dr. Wodzicki raised the question of census statistics, enquiring whether it was known what was the irreducible minimum population size for survival of the species. It was replied that fishermen could not remember any time when there were not many whales in the lagoons; but probably with this species recovery is possible with extremely low numbers, perhaps as few as half a dozen of each sex. A small number would not debar breeding as there would be no difficulty in finding mates.

WHALES IN THE PACIFIC SECTOR OF THE SOUTHERN OCEAN

By N. A. Mackintosh, Discovery Committee, London

[*Abstract*]

The Pacific sector of the Southern Ocean is little known but some inferences as to the population of whales can be based on limited direct observations and on analogy with other regions in high latitudes.

The Southern Ocean is a continuous belt of deep water, and there is a fundamental similarity in the oceanographical conditions in all longitudes. All pelagic organisms appear to have a circumpolar distribution, and this applies to whales, which in summer are most plentiful between the surface isotherm of about 1·5° or 2°C and the pack-ice to the south. Humpback whales, however, tend to become segregated in certain Antarctic areas the boundaries of which (south of 50°S) are taken to be I: 120°W - 60°W; II: 60°W - 0°; III: 0° - 70°E; IV: 70°E - 130°E; V: 130°E - 170°W; and VI: 170°W - 120°W. Those in Area IV migrate in winter to the tropical coasts of Western Australia and those in Area III to African waters. It is highly probable that those in other areas (except VI) similarly visit tropical coastal regions approximately to the north of them. There can be little doubt that humpbacks taken at New Zealand stations come from Area V in the Antarctic, and those from Area I (in the S.E. Pacific) probably migrate to the coast of Peru. It may be that humpbacks are absent from Area VI which is in the central Pacific sector. There appear thus to be several segregated communities of humpbacks, with one on each side of the South Pacific.

Blue and fin whales are found in a much more continuous belt and although they show a slight tendency to group themselves in the same

Antarctic areas, they may be seen in all longitudes, and do not assemble in coastal waters on their winter migration. Antarctic pelagic whaling factories have scarcely touched the Pacific sector. Observations from the Discovery Committee's ships, so far as they go, suggest that whales here are rather less plentiful than elsewhere, but in places very considerable numbers, at least of fin whales, have been seen. There is evidence that the "krill" (*Euphausia superba*) on which they feed is less abundant also in the Pacific than in other sectors.

Discussion

Dr. Murphy described the harpoon with lengthened head and fluke used in humpback whaling, and referred to information from the logbooks of Yankee whalers who chased the humpback in special regions, for example, the Galapagos.

Dr. Hubbs thought the evidence of north-south migration interesting, and wondered exactly how the power of directed migration and orientation is secured. From his own experience, he had found the grey whales to continue south just outside the limits of the kelp-beds, with some impetus directing them on the continued southern journey. If they strike the coast, they become caught between two impulses, one to continue south, and the other to extricate themselves from the kelp belt. Confusion results and the whale finally extricates itself by trial and error. Similar problems are posed to those of bird migration. It was pointed out that the grey whale and the humpback maintain parallel and peripheral courses with each other.

Dr. Yonge mentioned that there were quite a number of whales (humpbacks) inside the Barrier Reef of Australia in winter months. Not much was known in this case of their migratory activity. It was mentioned that the spout of the humpback was distinguishable from that of other whales by the short length, and the "bushy" effect at the top. Dr. Hubbs was doubtful of the identificatory value of the spout in any whales—except of course the sperm whale which has a forward-sloping spout. He described wide variation in whale spouts in the case of the grey whale, and discounted the recognition value of the spout. Dr. Murphy maintained that in South Georgia it was easily possible to distinguish by this means the blue whale, the fin whale, the humpback and the right whale. It was agreed that this may be due to the uniform atmosphere of South Georgia, which is much less variable than that of California.

Mr. Geddes mentioned the Cook Strait passage of the humpback, which was predictable within very narrow limits. He referred to the recovery from the integument of broken harpoons and projectiles of known origin as a marking device.

WHALING ON THE BRITISH COLUMBIA COAST

By Gordon Pike, Pacific Biological Station, Fisheries Research Board of Canada, Nanaimo, B.C.

Whaling activities were carried out by aboriginal Indians whose activities apparently centred around the region between Clayoquot

Sound and Kyuquot Sound on the west coast of Vancouver Island (Scheffer and Slipp, 1948). These primitive operations must have been very hazardous ones, calling for cool nerves and keen judgment since the whales were speared by hand from eight-man dugout canoes.

The first commercial whaling station in British Columbia opened in 1905 at Sechart in Barkley Sound on the west coast of Vancouver Island. Cachalot in Kyuquot Sound opened in 1919 and closed down in 1925. Cornwall (1928) gives an account of the decline in the availability of whales during the period, presumably basing his report on the observations of men who remembered the opening of the industry. In the Queen Charlotte Islands two stations employing five boats operated with interruption from 1911 to 1943, when the company disbanded because of administrative difficulties. The numbers of whales of each species in each year are shown in Table 1. Identification of all of these whales may not be accurate in some years. Particularly sei and finback whales may have been confused. The decline in catches of blue whales and sei whales is notable. No interest was shown again in British Columbia whaling until 1948 when a shore station was opened at Coal Harbour in the north-east part of Vancouver Island. This plant operated three killer boats equipped with Sven Foyn harpoon guns. The blubber oil was rendered by batch boiling in open vats heated by steam coils, and the bone oil in enclosed steam digesters. Standard fish meal reduction methods were used in producing the meal.

As required by the International Whaling Agreements biological inspection on all whales delivered to the whaling station was maintained. Records were kept of the species, sex, size, state of sexual maturity, pregnancies, etc. Some of the observations are given in Tables 2, 3, 4, 5, and 6.

Thirty-eight of the 64 female humpbacks were carrying young. It is not practical to determine sexual maturity in all cases but it is estimated that eight of the 64 female humpbacks were immature.

Three out of 20 female finbacks were pregnant and eight were apparently immature. The smallest finback with a foetus was 58 feet long.

All sperm whales taken were males.

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TABLE 1.—WHALE PRODUCTION IN BRITISH COLUMBIA

Year	Sperm[2]	Blue	Fin	Hump	Sei	Others[1]	Vancr. Is.	Naden Hr.		Rose Hr.	Total
1911	—	—	—	—	—	—	890		309		1199
1912	—	—	—	—	—	—	583		526		1109
1913	—	—	—	—	—	—	486		219		705
1914	—	—	—	—	—	—	320		253		573
1915	—	—	—	—	—	—	137		92		229
1916	—	—	—	—	—	—	175	107		121	403
1917	—	—	—	—	—	—	—	—	—	—	—
1918	—	—	—	—	—	—	246		254		500
1919	35	7	217	65	74	—	—	—	—	—	432
1920 [3]	56	26	149	98	121	—	146		347		493
1921	—	—	—	—	—	—	—	—	—	—	—
1922	38	4	94	50	1	—	—	—	—	—	187
1923	94	62	166	78	53	2B.	138		316		455
1924	83	56	125	47	100	3	141		274		414
1925	76	29	135	40	68	3B.	82		269		351
1926	80	14	124	25	25	1R.	—	58		211	269
1927	82	10	138	21	7	—	—	94		164	258
1928	83	47	140	21	13	1B.	—	78		227	305
1929	146	16	168	9	67	1B.	—	115		292	407
1930	147	10	62	12	89	—	—	88		232	320
1931	—	—	—	—	—	—	—	—		—	—
1932	—	—	—	—	—	—	—	—		—	—
1933	190	1	17	—	1	—	—	—		209	209
1934	265	—	71	14	—	—	—	138		212	350
1935	175	6	20	1	—	—	—	—		202	202
1936	311	3	48	14	2	—	—	157		213	370
1937	265	1	44	7	—	—	—	139		178	317
1938	252	4	50	4	—	—	—	137		173	310
1939	—	—	—	—	—	—	—	—		—	—
1940	126	2	90	2	—	—	—	—		220	220
1941	233	1	67	27	—	—	—	68		203	271
1942	130	1	25	7	—	—	—	—		163	163
1943	69	—	15	7	—	—	—	—		91	91
1944	—	—	—	—	—	—	—	—		—	—
1948	28	—	39	113	2	—	182	—		—	182

[1] Other Species (B = bottlenose; R = right).

[2] Whaling grounds near Rose Harbour and Naden Harbour supplied a relatively large proportion of sperm whales.

[3] Totals from Department of Fisheries. Individual species from Kellogg (1931).

TABLE 2.—AVERAGE LENGTHS OF WHALES DELIVERED TO COAL HARBOUR BY SPECIES AND SEX.

	Female		Male		
Species	No.	Av. Length	No.	Av. Length	Total
Humpback	64	40·1	49	38·9	113
Finback	20	58·1	19	58·3	39
Sei	1	47·0	1	46·0	2
Sperm	—	—	28	45·3	28
					182

TABLE 3.—NUMBERS OF HUMPBACK WHALES BY LENGTH GROUP, SEX, AND MONTH

Length group ft.	30 - 34		35 - 39		40 - 44		45 - 49		
	Female	Male	Female	Male	Female	Male	Female	Male	Total
June	—	—	6	4	6	8	2	1	27
July	1	2	10	12	8	9	5	1	48
August	1	—	4	2	3	3	2	—	15
September	2	—	7	5	7	2	—	—	23
Total	4	2	27	23	24	22	9	2	113

TABLE 4.—LENGTH DISTRIBUTION AND SEXUAL CONDITION OF FEMALE HUMPBACK WHALES BY MONTHS

Length group ft.	-34		35 - 36		37 - 39		40 - 44		45 - 49		Total	
Month	No.	G[1]	No.	G	No.	G	No.	G	No.	G	No.	G
June	—	—	3	—	3	1	6	1	2	2	15	4
July	1	—	2	—	8	1	8	3	5	2	23	6
August	1	—	1	—	3	1	3	1	2	2	10	4
September	2	—	2	—	5	2	7	1	—	—	16	3
Total	4	—	8	—	19	5	24	6	9	6	64	17

[1] Whales carrying young.

TABLE 5.—NUMBERS OF FINBACK WHALES BY LENGTH GROUP, SEX, AND MONTH.

Length group ft.	45 - 49		50 - 54		55 - 59		60 - 64		
	Female	Male	Female	Male	Female	Male	Female	Male	Total
June	—	—	—	—	1	1	2	3	7
July	1	—	—	1	1	—	1	—	4
August	1	—	2	1	4	7	6	3	24
September	—	—	—	—	1	1	1	1	4
Total	2	—	2	2	7	9	10	7	39

TABLE 6.—NUMBERS OF SPERM WHALES BY LENGTH GROUPS AND MONTHS.

Length group ft.	20 - 44	45 - 49	50 - 54	55 - 59	Av. size ft.
June	—	4	2	—	47·8
July	6	3	—	1	45·5
August	2	2	—	—	43·0
September	4	4	—	—	44·4
Total	12	13	2	1	

Discussion

The paper was read by Dr. R. E. Foerster, who in reply to a question by Dr. Hubbs stated that the season of operation was from mid-June to mid-September. Dr. Falla asked whether there was any indication of two seasons. Dr. Foerster replied that field observations were not sufficient to give any real indication at present. The season was determined by the weather rather than statutorily. In reply to a further question it was stated that stomach contents observations were now being made.

A CONTRIBUTION TO THE STUDY OF THE HUMPBACK WHALE BASED ON OBSERVATIONS AT NEW ZEALAND SHORE STATIONS

By W. H. Dawbin, Victoria University College, and R. A. Falla,
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In the present century there have been two shore-whaling stations on the New Zealand coast operating with sufficient regularity to provide useful biological data. This relates almost entirely to the humpback (*Megaptera nodosa*) as the number of whales of other species taken has been negligible.

The station at Whangamumu on the north east coast of the North Island operated from 1890-1910 using open boats and nets, and from 1910-1933 with steam and motor chasers. Observations based on the 1911 season have been published by Lillie (1915) and some further data were summarized in 1932 by Ommanney (1933). The further data here presented from this station are based on annual returns of numbers of whales taken. No analysis of catch is available for these years, nor biological data except a few pertinent observations reported by the men engaged on the station.

The Te Awaiti station is situated in Tory Channel near Cook Strait and is still operated by Mr. J. A. Perano and his sons. From this station the same data of annual returns are available, and since 1946 some analysis of the catch. This was begun by one of us (R. A. F.) in collaboration with Mr. J. R. Eyles who was employed at the works, and who continued recording in 1947. Finally W. H. D. paid several visits in the 1948 and 1949 seasons, making biological investigations and collating records. A more detailed account of results from these studies will be published at a later date.

Numbers of Whales in New Zealand Catches

The total number of whales captured or sighted from the New Zealand coast is very small compared with those for the coast of Africa and for West Australia when whaling occurred there; it seems to indicate that only a small whale population passes through New Zealand waters. The returns from Whangamumu are for both the winter and summer seasons, and range from 27 in 1916 to a maximum of 74 taken in 1927, with an average of 48 for the years 1912 to 1931, which was the last season of full scale operations.

The returns for Marlborough Sounds are for the winter season only and from 1915-1938 averaged 50. Since 1938 the greater efficiency of the catching methods has increased the average to 94. A better guide to the numbers of whales in New Zealand waters would be a record of those sighted from localities such as Cook Strait where the migrating population must pass through a narrow belt. From 1944-1948 the number has ranged from 150-186. A number of whales must pass through unobserved at night or during periods of poor visibility, and it is unlikely that less than 300 whales pass through Cook Strait during each northwards migration.

The only attempt to test and exploit the waters further off the New Zealand coast by pelagic whaling was made by three Norwegian companies in 1912. The ships of two firms left for other areas after poor results from New Zealand waters, and ships of the remaining firm captured only 133 whales in spite of operating along both the North and South Island coasts during more than eleven months' operations. From these results it is apparent that large numbers of whales do not pass close to the New Zealand coast or through the readily accessible coastal waters.

Captures at New Zealand shore stations have been almost exclusively humpback whales. There have only been six specimens of blue whales captured since 1930 and none prior to that year. Thirteen sperm whales have been captured since 1920 but nine of these were captured in one day when a school passed through Cook Strait in 1947. Between 1915 and 1927 twelve right whales were captured. These are the only available records of species other than humpbacks being taken at New Zealand shore stations since 1912. That others may have been taken but not listed in the station records is indicated by a photograph of a sei whale taken at Whangamumu by Dr. W. R. B. Oliver.

MIGRATION OF THE HUMPBACKS

The results of whale marking have clearly confirmed the conclusions reached by a number of investigators, that humpbacks are segregated into distinct stocks in the Antarctic waters and migrate to and from their particular areas without any evidence of lateral intermixing (Rayner, 1940). While no whale marking has been carried out in Hjort, Lie and Ruud's "Area V" (Rayner, 1940 and 1948), it has been presumed that the humpback stock in this area migrates northwards via the coasts of New Zealand and East Australia. No whale marked in any of the other areas has been obtained in the New Zealand catches. There have, however, been two records of the recovery of local harpoon heads 7 and 19 years after they were first imbedded (Ommanney, 1933), showing that some of the whales return at least at intervals to the same place in New Zealand waters.

Although the Ross Sea was reported to contain great numbers of humpback whales (Ross, 1847) and was one of the major centres in the earlier days of pelagic whaling, there has been very little catching carried on there since 1931. Catches of humpbacks for 1929-1930 by Norwegian pelagic whalers in Area V were 643 (Hjort, Lie & Ruud, 1934) and for 1930-31 had dropped to 173. For the whole period 1933-45 very little whaling was carried out in Area V and only 28 humpbacks were captured as compared with more than 6,000 each in Areas III and IV (International Whaling Statistics, No. 17, p. 14). Thus there is much less information available about humpback stocks from which the New Zealand populations is probably derived, than that of any of the other areas.

North of Antarctic waters, Kellogg (1928) states that whaling operations for humpbacks are carried on in the vicinity of Campbell Island during the Antarctic summer. It is probable that this statement is inferred from Lillie (1915, p. 111) where, in discussing humpback migrations, he mentions that whaling operations in the summer are carried on from Campbell Island, but he does not state the species captured there. All the catches made there during the century have been small and have been composed exclusively of right whales. Whalers who operated on the island state that no humpbacks were sighted. From 1942 to the present time a coastwatching and weather station has been maintained at Campbell Island and has frequently included a trained zoologist in the party. Again no records of humpbacks were obtained although right whales were seen in the bays. Similar stations at Auckland Islands 1942-45 reported practically no whales of any species. No records of humpbacks have been obtained from the Chatham Islands, which were the centre of a summer sperm whale area last century.

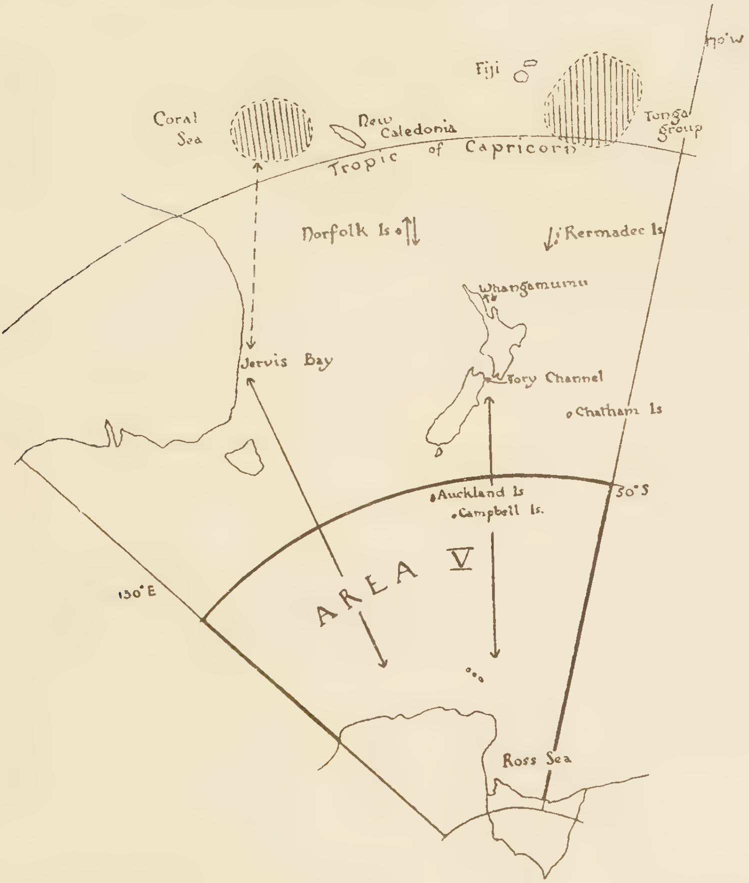
In New Zealand waters the first northwards migrating humpbacks are usually captured from Te Awaiti near mid-May, the earliest recorded date being 4th May for the 1948 season. A commencement in June is regarded as a late season, but in 1945 a whale was caught on 4th June and no more were seen until 21st June, after which a steady flow commenced. The last north-bound whales are usually observed at approximately mid-August but earlier or later records are usually associated with a corresponding deviation of the date of commencement. Thus the duration of the northwards migration through Cook Strait is usually 12-13 weeks. Further north, the station at Whangamumu usually commenced captures in early June, but sometimes it commenced in late May. In one exceptional season (1930) no whales were captured until late July. The last of the north-bound humpbacks travelling off the East Coast past Whangamumu are usually seen about mid-August which is the same date as for those which pass through Cook Strait and then continue out off the west coast of the North Island. At both localities there is a tendency towards a gradual increase in the numbers which pass through each week during the season until a maximum is reached near the middle of the season. This is followed by a gradual decrease until only an occasional straggler is seen by mid-August.

There are indications of a separate parallel route for humpbacks from Area V other than that followed by the New Zealand stock. At a similar latitude but much further west, there are a few records from Jervis Bay (Lat. 35° S.) on the east coast of Australia. Whaling was carried on there by a Norwegian factory ship and chasers in 1912, but work did not begin until September so the catch for that year is presumably taken from the returning southwards migration. In 1913 some whales were captured in May and June but the main migration did not begin until July. The season ended in October with an oil yield of 9,500 barrels (Dakin, 1934, p. 129) which would probably represent 200-250 whales for the complete season. Although there is no mention of a break in the middle of the season between the northwards and southwards migrations, it seems likely that a break similar to that in New Zealand would occur. In 1912 operations did not commence until September and lasted until the end of November. The oil yield for that period which probably represents catches during the southward whale migration was 3,000 barrels, so it is probable that only 70-100 humpbacks were captured. As the number of humpbacks passing close to the East Australian coast is very much less than along the west coast where captures of over 3,000 were made during each of the years 1936 and 1937, there has been very little whaling from the east coast during this century.

Close to the possible migration route for New Zealand humpbacks there are the Kermadec Islands which have never been the centre of extensive humpback whaling, although a considerable number of sperm whales have been captured in adjacent waters. Oliver (1911) recorded no humpbacks during the northwards migration, although large numbers were seen during the later southwards migration.

At Norfolk Island, there have been a number of whaling ventures. Lillie (1915) stated that the three months July-September were the busy time for the whalers at Norfolk Island. A longer season is given by L. L. White (1931) who states that it lasts without a break from June to November. The catch during this century has been almost entirely humpbacks but at the start of South Pacific whaling, sperm whale grounds were found nearby (Dakin, 1934). The humpbacks are travelling north in the early part of the season and according to Mr. Jagger of Whangamumu who visited the area several times, some are seen moving southwards after the first week of September. The only available data on humpback catches north of Norfolk Island is from the plottings on the charts by Townshend (1935). From these it can be seen that the two major tropical whaling grounds have been an area in the neighbourhood of the Tonga group which is probably the northern limit of humpbacks passing New Zealand, and another in the

Coral Sea north-west of New Caledonia which is probably the northern limit for humpbacks migrating up the East Australian coast. Both these tropical areas have been the centre of large catches. Catches of humpbacks from the neighbourhood of Fiji and other Pacific Islands were insignificant in comparison, but many sperm whales have been captured. At both the Tonga group and the Coral Sea there were a few catches of humpbacks as early as July but by far the majority were in August and September, and a few were taken in October.


170°W
Fiji
Coral Sea
New Caledonia
Tonga Group
Tropic of Capricorn
Norfolk Is
Kermadec Is
Whangamumu
Jervis Bay
Tory Channel
Chatham Is
Auckland Is
Campbell Is.
50°S
AREA V
130°E
Ross Sea

Map showing the regions of breeding concentrations of humpback whales from Area V, and the localities past which migration has been observed.

From the unimodal peak in catching indicated by these figures, it seems highly likely that these centres represent approximately the northern limits of the migration of humpbacks from Area V, and it is probable that they are the mating and calving grounds. Ommanney (1933) records Mr. Cook's observations of mating in the neighbourhood of Tonga. The presence of 2-2½ inch foetuses in south bound females caught at Whangamumu in the summer season (October, November) agrees with this. Calving probably occurs during the period spent near the Tonga group as cows accompanied by calves are seen in the later part of the Norfolk Island season where humpbacks moving southwards are usually first seen after the first week in September. Whaling ceased there about 1926 (Dakin, 1934) but was resumed in 1948, and Mr. King visited the locality in August. He states that three whales were seen on August 29th and then the numbers steadily increased until "dozens per day" could be seen. He stated that some had calves before arrival at this time. Oliver (1911 and 1922) recorded humpbacks frequenting the Kermadec group in large numbers with their calves from the middle of August to the end of November in 1908, but they were most common in the group during October and November.

The "summer" season during which southwards migrating humpbacks were caught from Whangamumu usually began at the start of October and ended in late November, but on one occasion three southward moving whales were caught in late September. The season has twice extended until mid-December, the latest catch of a season being made on December 18th. During this period the majority of the cows were found lactating and accompanied by calves of approximately 15 feet in length. Very few humpbacks pass through Cook Strait in the southwards migration so most of the earlier north bound population must return by some other route. After mid-December the humpbacks must be to the south of New Zealand, but there is no information available about the migration beyond New Zealand.

Sex Ratios

While the records of sex ratios of humpbacks at different phases of the migration to and from the southern ocean are very meagre the available evidence raises questions that emphasize the need for more data. For the two seasons (1947 and 1948) during which sex and approximate size determinations were made for all the whales brought to the Te Awaiti station in New Zealand, there has been no definite evidence of sex or obvious age group segregation at any part of the three months during which the whales migrate past this locality. Although the total captures for which the sex was determined is small (170), it is of interest that there is a significantly larger proportion of males than females (96 males and 74 females). This was also the case for each of the months June, July and August individually but in May eight males were captured and 14 females. The latter figures are too small to show whether this indicates that more females are likely to be present at the front of the migrating population.

Although an analysis of the sex ratios of humpback foetuses shows that 57·4 per cent were males, analysis of the catches for Antarctic pelagic whaling show a clear excess of females in these waters, 7,471 females and 5,717 males (Mackintosh, 1942). Matsuura's (1940) analysis of 1938-39 Japanese catches in Hjort, Lie and Ruud's Area IV show a similar result (174 females and only 74 males). In the tropics there is a clear excess of males which Mackintosh has shown as especially marked from the west coast of Australia between latitudes 21° and 26° S. (754 males to 469 females). A comparison of Matsuura's figures with the latter are of particular interest as the results of whale marking have shown clearly that the West Australian humpbacks migrate to and from Area IV (Rayner, 1940). At Natal (30° S.) the sex ratios are about equal, but in New Zealand there is already an excess of males at 41° S.

It is clear from all these observations that partial segregation of sexes must occur at some phase of the migration. Matthews (1937) referring to African catches suggested that the differences from the ratios in Antarctic waters are due to females proceeding south to the feeding grounds immediately after pairing and parturition, while the males probably linger for a longer period on the breeding grounds in tropical waters and are more easily captured. Mackintosh (1942) has suggested that some of the males may remain in tropical waters during the summer. These suggestions would not explain any marked difference between Antarctic and Temperate zone ratios during the northwards migration before the whales reach the tropics. Although the figures for two seasons from Tory Channel are alone inconclusive, the whalers state that there has always been an excess of males in the Tory Channel catch and this observation was also reported by Ommanney (1933). It appears that some other segregation of sexes must occur much earlier than is suggested by the above hypothesis. A possible alternative explanation by Mackintosh, that the males do not travel so far south as the females on the southwards migration would agree more closely with the observations from New Zealand. It would account for the high ratio of females in the most southern catches, and allow for the addition of more males to the population before the northwards migration passes through the Temperate zone. At present there is insufficient data on catches from parts of Area V south and north of New Zealand, to draw any further conclusions. It emphasizes the need for records from a much greater range of latitudes than is available at present.

Foetuses at Tory Channel

As the whales captured here are well advanced in their northwards winter migration, it would be expected that the females would be in late pregnancy. Ommanney (1933) states that he was told that most of the cows caught are carrying foetuses about 14 feet in length, and Lillie (1915) in July at Whangamumu saw a foetus 13½ feet in length. During 1946 approximately 15 foetuses in an advanced state of development were seen. In 1947, one cow captured in June was carrying a foetus about 13 feet in length, and two captured in July were carrying foetuses 8 - 9 feet in length, but no other foetuses were found. In 1948 no foetuses could be detected. This was certainly not due to consistent immaturity of the females captured. Even allowing a margin of error in lengths estimated on the slipway for whales which Mr. Eyles was unable to measure by tape, it appears that a high proportion of the females were of mature size (over 40 feet). Of 10 examined in detail, six were females and while three were immature and under 40 feet in length (36 ft. 6 ins., 35 ft., 36 ft. 8 ins.) the three of 40 ft. 9 ins., 42 ft., and 46 ft. 11 ins., all had corpora lutea present in the ovaries and were not lactating. Careful dissection of the uterus showed no trace of a foetus. No explanation of this unusual condition is at present offered.

Feeding

On the northward migration the stomachs of most of the whales migrating past Cook Strait are empty, but occasional whales contain crustacean remains, or more rarely fish. Of the ten examined closely eight were empty, one contained many gallons of very finely macerated Crustacea and one contained the remains of fish of quite large size. At Whangamumu the north bound whales were usually also empty, but according to Mr. King the south bound whales were sometimes seen feeding, and often contained food in the stomach. At this time and especially after the whales had moved south, red patches of "whalefeed" appeared around the Bay of Islands. The organisms forming these patches, which are also reported from this locality by Matthews (1932), have not yet been collected and identified, but it is at least probable that they are *Munida gregaria* as the latter has been frequently observed off the South Island coast at about this time of year. (Young, 1925, Marine Dept. Annual Reports, 1928-1935.)

Matthews (1932) reported the occurrence of the Grimothea stage of *Munida gregaria* from Tory Channel, Cook Strait, and was informed that large areas of the sea in Cook Strait had been coloured red by whalefeed and this has been observed by the writers in December and January. Matthews suggests that the great abundance of shoals of whalefeed may have an important bearing on the migrations of the humpback whale in New Zealand seas. However he does not state the time of year at which his records of whalefeed were made, and all the occurrences which have been dated show that the peak months for the Grimothea stage of *Munida gregaria* are December to February in New Zealand waters. By this time almost all the migrating humpback whales have moved south of New Zealand and there is as yet very little evidence of other than very occasional feeding by them in New Zealand waters.

SUMMARY

Two main shore stations have engaged in whaling off the New Zealand coast during this century. Practically only humpbacks have been taken at both stations. The annual catch of the station at Whangamumu which operated for two seasons a year averaged 48 until it ceased full scale operations in 1931. That at Tory Channel had a similar annual catch, but operated only during the winter seasons. Improved methods in the last decade raised the total to nearly 100 per year.

Probably not fewer than 300 whales pass northwards through Cook Strait per season. The season for catching north bound whales at both stations has been from late May to early August. While many mature females are usually in late pregnancy at this time, none were pregnant in 1948 in spite of a number being definitely mature and non-lactating. No south bound whales are now captured as they do not return through the area traversed from the existing station near Cook Strait. South bound whales that were captured from the station at Whangamumu were caught in October and November, and many females were accompanied by young calves. The sex ratio in New Zealand waters has shown a 56 per cent. male ratio during the last two seasons but there is no definite evidence of sex segregation during the period of migration through these waters. The stomachs of north bound whales are empty but there is evidence that some of the south bound whales feed in New Zealand waters.

While there are no records of humpbacks from the vicinity of islands south of New Zealand, catches have been made at Eastern

Australia, Norfolk Island, and from two tropical concentrations one at the Tonga group and the other at the Coral Sea. It is probable that the latter are the northern limits and the pairing and calving grounds for Area V stock. With the prohibition since 1938 on pelagic whalers catching humpbacks south of the 40° S., the only available source of information on Area V humpbacks is that obtainable from shore stations. At present the New Zealand shore station is the only one operating regularly that catches whales from Area V stock, and until regular whaling recommences in other parts of the Area, it can be the only source of information on Area V humpbacks.

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DISCUSSION

With regard to the passage of whales at night which are thus inaccessible to counting, Dr. Hubbs raised the point as to whether few or many whales travel in darkness. The results available are negative so far. There is no evidence that whales definitely do not pass at night—but neither is it apparent that they do. Sonic equipment gives no indication of night movement. Dr. Falla held that the indications were that there was continued night movement. Catches were frequently made just at dusk, and whales were frequently sighted and caught up with after nightfall. During the war, radar equipment in Cook Strait definitely selected whale echoes, leaving no doubt of the passage of whales at night.

Mr. Fleming referred to work during the war in the detecting of night feeding birds in the Strait, and stated that at the same time further noises had been detected which had been put down to whales. Dr. Hubbs pointed out that most marine mammals undergo exertion for long periods, and are assumed not to need much resting.

Dr. Murphy mentioned that New Zealand was in the feeding waters of the humpback. We should expect the north-bound whales to have Euphausiids in their stomachs, and probably to condition up on Lobster-Krill (*Munida*) towards the north. Mr. Dawbin pointed out that there was an anomaly in that most of the north-bound whales were empty, except for one with macerated crustacea in the stomach. On the south migration, during the swarming of *Munida* they were found to be full.

Mr. Geddes thought that the Tory Channel operators would affirm that the humpbacks move at night. He gave a description of night-time whaling routine.

Dr. Oliver stated that, although Mr. Dawbin had reported only humpbacks from Whangamumu, he had recorded one sei whale 40 feet long, with crustacea in its stomach.

Mr. McCann advanced the idea that the humpback did not feed at all on its northern trip. The abdominal cavity was probably largely occupied by the growing foetus *in utero*, and the alimentary canal restricted in extent and remaining empty. He cited the analogy in his own work on the breeding of lizards, where the large eggs or embryos occupied the body cavity and the stomach and intestines were quite empty. In the case of the whales the fat reserve would probably last a considerable time.

Dr. Hubbs stated that the grey whale showed little or no evidence of feeding on the south journey, but fed on the northbound trip. But there was probably a sexual difference here. From one male specimen two barrels of sardines had been taken.

Further discussion arose as to the disproportionate sex ratio reported by Mr. Dawbin in the Tory Channel whales. It was queried how much this might result from selection by the gunner, in picking out the biggest females, but it was pointed out that this factor would not apply in the case of the humpback where there is no appreciable size difference in the sexes. Mr. Dawbin drew attention to the interesting point that the difference in sex ratio varies in different latitudes, being roughly consistent for the same latitude at any longitude. The whalers alleged that the female was first selected by the gunners, and that the male stays about and is easily taken later. Dr. Murphy stated that at South Georgia, the whales were found largely in pairs, and that the only selection was an attempt to get them both.

DIVISIONAL DISCUSSION ON PROBLEMS OF BIRD MIGRATION IN THE PACIFIC

MIGRATIONS OF SHORE BIRDS IN THE CENTRAL PACIFIC

By Rollin H. Baker, Museum of Natural History, University of Kansas, Lawrence, Kansas, U.S.A.

Shore birds are conspicuous members of the fauna of the islands of the Pacific. On many of these remote oceanic islands, land birds are absent or few in number and shore birds and oceanic birds are the only kinds of birdlife present.

Only a few birds have been banded in the Pacific, and the knowledge which comes from the recovery of banded birds gives but little aid to the students of movements of shore birds in the Pacific. As a result, evidences of migrational behaviour are obtained principally from: (a) sight records by competent observers, (b) data from specimens collected, (c) known areas of breeding and wintering. Evidences from these sources have been used by Stickney (*Amer. Mus. Novit.*, No. 1248, 1943) in her discussion of five kinds of shore birds in the Pacific. As her paper points out, year around observations, especially on tropical and subtropical Pacific islands, are needed to analyse most effectively the migrational habits. Some additional pertinent information was obtained by the present author when he was stationed in the Micronesian islands (Guam, Ulithi, Peleliu) from January to November, 1945, where he made observations and collections of shore birds in that time. In addition, other field observers in the armed forces obtained records of shore birds in Micronesia and other areas of the Pacific in the period from 1944 to 1946, and these have been drawn upon.

The shore birds known to visit the central Pacific (Micronesia, the Hawaiian Islands, adjacent islands) breed in the Northern Hemisphere (the one exception is the resident *Himantopus himantopus knudseni* of the Hawaiian Islands). Observations indicate that migratory shore birds move southward from northern breeding grounds beginning in July and continuing until September or October and that they move northward from tropical and temperate wintering grounds beginning in February and continuing until May.

Thirty-three kinds of migratory shore birds have been recorded from the Central Pacific area. Of these, 19 kinds are considered to be regular visitors and 14 kinds occasional visitors; these are listed in Table 1. Eighteen of the 33 species come from breeding grounds in Asiatic areas, nine from both American and Asiatic breeding grounds, and six (two regular visitors) from American breeding grounds. Twenty-one of the 33 species visit wintering grounds on the Asiatic side of the Pacific and each also ranges eastward to the Central Pacific, four winter both in Asiatic and American areas, seven (one regular visitor) winter on the American side of the Pacific with extensions of ranges into the Central Pacific, and one winters almost exclusively in the islands of the Pacific.

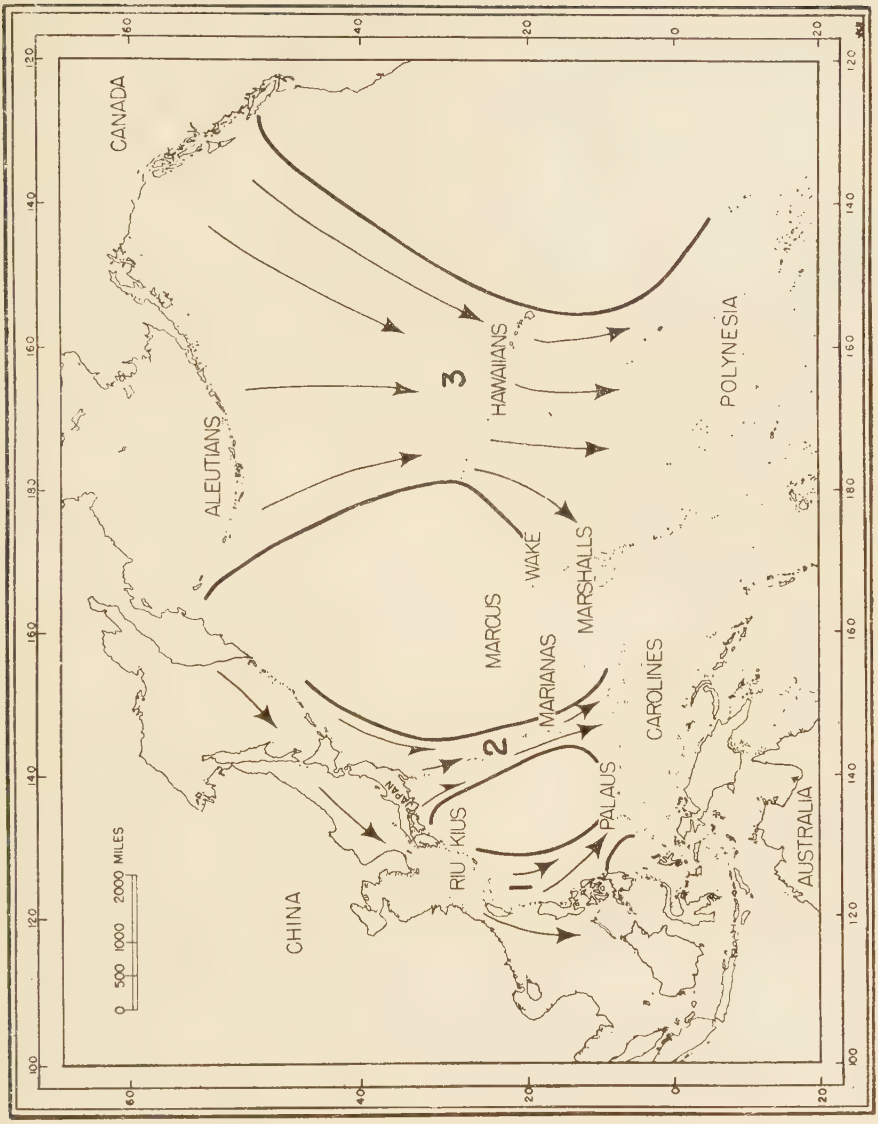
TABLE I.—MIGRATORY SHORE BIRDS RECORDED FROM THE CENTRAL PACIFIC

Regular Visitors	Occasional Visitors
Pluvialis dominica fulva	*Squatarola squatarola*
Charadrius mongolus stegmanni	*Charadrius hiaticula semipalmatus*
Charadrius leschenaultii	*Charadrius dubius curonicus*
Numenius phaeopus variegatus	*Charadrius alexandrinus dealbatus*
Numenius tahitiensis	*Charadrius vociferus vociferus*
Numenius madagascariensis	*Tringa melanoleuca*
Limosa lapponica baueri	*Limnodromus griseus scolopaceus*
Tringa nebularia	*Gallinago gallinago gallinago*
Tringa glareola	*Gallinago delicata*
Actitis hypoleucos	*Calidris tenuirostris*
Heteroscelus brevipes	*Calidris minutilla subminuta*
Heteroscelus incanus	*Calidris melanota*
Arenaria interpres interpres	*Calidris ferruginea*
Gallinago megala	*Limicola falcinellus sibirica*
Crocethia alba	
Calidris minuta ruficollis	
Calidris acuminata	
Phalaropus fulicarius	
Phalaropus lobatus	

It is evident, as shown by the location of breeding and wintering grounds, that most of the shore birds migrating over Pacific waters have been derived from Asiatic stocks; only two regular visitors are restricted in their breeding grounds to Nearctica and one regular visitor winters almost entirely on the American side of the Pacific. It is therefore probable that the migrational behaviour of shore birds in the Pacific was initiated from the Asiatic side of the Pacific Ocean. Island chains adjacent to the Asiatic mainland may have been utilized initially by shore birds and having once become accustomed to making relatively short flights from island to island, shore birds may have extended the breadth of their wintering ranges eastward and as a gradual adaptation began to make the longer flights necessary to reach the more isolated islands of the Pacific. In contrast, if one observes a map of the Pacific area he will note that there are few coastal or off-shore islands bordering the emergent coastline of the American side of the Pacific, and vast expanses of open water separate the American mainland from the Hawaiian and Polynesian groups of islands. Probably the absence of island chains ("stepping-stone islands") on the American side may account, in part, for the paucity of winter visitors of truly American species in the Pacific area. Nevertheless, brisk trade winds from the north-east might be an aid to birds migrating from Nearctica to Oceania.

The long flights made by shore birds from the Aleutians to the Hawaiian Chain may have been initiated by birds first moving northward from wintering grounds; on reaching the Hawaiian Islands, the birds may have flown out over the open water to reach the Aleutian Islands and more northern islands in the Bering Sea. It seems plausible to assume that the birds then became adjusted to the return flight over the same route to the wintering grounds.

Today, migratory shore birds probably reach every island in the Pacific. Extensive tidal flats, especially on the leeward sides of the islands, offer excellent winter feeding grounds. In addition, the absence of resident, competitive species and the absence of native predatory animals make the islands of the Pacific Basin favourable wintering areas.


CANADA
ALEUTIANS
3
HAWAIIANS
POLYNESIA
WAKE
MARSHALLS
MARCUS
MARIANAS
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160
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100

Routes of migration used by shore birds in the Central Pacific area: (1) the Asiatic-Palauan Flyway; (2) the Japanese-Marianan Flyway; (3) the Nearctic-Hawaiian Flyway.

A study of the recorded information indicates that the migratory shore birds visiting the Pacific Ocean area have formed definite patterns of migration and their movements are limited to rather well-marked flyways. Three principal flyways are discernable: (1) Asiatic-Palauan Flyway; (2) Japanese-Marianan Flyway; (3) Nearctic-Hawaiian Flyway. These are shown in the text figure.

(1) *Asiatic-Palauan Flyway.* There appears to be a migrational route extending almost due south from the Japanese and Riu Kiu islands to the Palau Islands. Some birds may migrate via the Philippines and other birds may pass east of the Philippines. Birds reaching the Palaus may move into the western Carolines and/or may pass southward in the direction of New Guinea. Delacour and Mayr ("Birds of the Philippines", 1946: 68-74) record 46 kinds of shore birds in the Philippines; 20 kinds are known to use the Asiatic-Palauan Flyway (see Table 2). Of these 20 kinds, there are eight kinds which have not been recorded in the Marianas, or other parts of the Central Pacific.

TABLE 2.–SHORE BIRDS RECORDED ALONG THE ASIATIC-PALAUAN FLYWAY

Regular Visitors	Occasional Visitors
Pluvialis dominica fulva	*Charadrius dubius curonicus*
Charadrius mongolus stegmanni	*Charadrius alexandrinus dealbatus*
Charadrius leschenaultii	*Calidris tenuirostris*
Numenius phaeopus variegatus	*Calidris ferruginea*
Numenius madagascariensis	*Calidris minutilla subminuta*
Limosa lapponica baueri	*Limicola falcinellus sibirica*
Tringa nebularia	
Tringa glareola	
Astitis hypoleucos	
Heteroscelus brevipes	
Arenaria interpres interpres	
Gallinago megala	
Calidris minuta ruficollis	
Calidris acuminata	

(2) *Japanese-Marianan Flyway.* Shore birds from breeding grounds in Asia, the Aleutian and Bering Sea areas, and probably Alaska may move to and from the southern wintering grounds by way of the Asiatic coast and adjacent island chains, thence south-east to the Japanese Archipelago from where they may move through the Bonin and Volcano islands and the Marianas. From northern Micronesia birds may spread in fanlike fashion through the Central Pacific islands. As shown in Table 3, 17 kinds of birds are known to utilize this flyway.

TABLE 3.–SHORE BIRDS RECORDED ALONG THE JAPANESE-MARIANAN FLYWAY

Regular Visitors	Occasional Visitors
Pluvialis dominica fulva	*Squatarola squatarola*
Charadrius mongolus stegmanni	*Numenius tahitiensis*[1/]
Numenius phaeopus variegatus	*Numenius madagascariensis*
Limosa lapponica baueri	*Tringa glareola*
Actitis hypoleucos	*Gallinago gallinago gallinago*
Heteroscelus brevipes	*Calidris minuta ruficollis*
Heteroscelus incanus	
Arenaria interpres interpres	
Gallinago megala	
Crocethia alba	
Calidris acuminata	

[1/] rare straggler.

(3) *Nearctic-Hawaiian Flyway.* Shore birds from breeding grounds in Arctic America, the Aleutian Islands, the Bering Sea area, and Asia may fly in a southerly direction along a "broad front" to the Hawaiian Islands. From the Hawaiian Chain the birds may continue southward or move south-westward as far west as the Marshall Islands or south-eastward as far as the New World. Sixteen kinds of migratory shore birds have been recorded within the limits of this flyway (see Table 4); seven of these have not been recorded from the other Pacific flyways (except as occasional stragglers). Two phalaropes (*Phalaropus fulicarius* and *P. lobatus*) are included but may not follow this migrational pattern. The Bristle-thighed Curlew (*Numenius tahitiensis*) utilizes this flyway almost exclusively.

TABLE 4.—SHORE BIRDS RECORDED ALONG THE NEARCTIC-HAWAIIAN FLYWAY

Regular Visitors	Occasional Visitors
Pluvialis dominica fulva	*Squatarola squatarola*
Numenius tahitiensis	*Charadrius hiaticula semipalmatus*[2]
Heteroscelus incanus	*Charadrius vociferus vociferus*
Arenaria interpres interpres	*Limosa lapponica baueri*
Crocethia alba	*Tringa melanoleuca*[2]
Phalaropus fulicarius[1]	*Limnodromus griseus scolopaceus*
Phalaropus lobatus[1]	*Gallinago delicata*
	Calidris melanota
	Calidris acuminata

[1] This flyway concept may not be applied to the migratory behaviour of the phalaropes which probably winter chiefly at sea. *P. lobatus* probably migrates through Micronesian waters but has not been recorded there.

[2] Indicates species not recorded from the Hawaiian Islands; recorded in the Marshall Islands.

South of the Central Pacific there is less evidence that shore birds restrict themselves to definite wintering areas. It appears likely, however, that the Nearctic-Hawaiian Flyway supplies to Eastern Polynesia and probably to most of Central Polynesia the largest wintering populations of migratory shore birds. The above outline of flyways does not include all possible routes of migration but indicates the principal routes.

Discussion

In the absence of the author the paper was read by Dr. R. C. Murphy.

Dr. Falla said that in general migratory shore birds would appear to reach New Zealand by way of the central Pacific flyway. They regularly reached the Auckland and Campbell Islands.

ON THE ORIGIN OF BIRD MIGRATION IN THE PACIFIC

By Ernst Mayr, American Museum of Natural History, New York

The history of the Pacific Ocean is one of the most disputed problems of geology. The chief difficulty of this problem is that most of the clues to its solution are covered by many thousands of feet of water. The geologist is thus forced to utilize every scrap of evidence no matter how indirect it may be. One of his potential sources of evidence is zoogeography. If the present distribution of animals permits the drawing of definite conclusions as to the history of these distributions, as has been claimed by so many zoogeographers, it would certainly be most helpful to the geologist. I have pointed out previously (Mayr, 1944) that the optimism of this school is not justified. Zoogeographical evidence can be used for paleogeographical speculations only if dispersal and other complications are thoroughly taken into consideration.

Similar caution must be exercised before the results of another potential source of evidence can be utilized, namely, that derived from the routes of migrating birds. Again and again in the history of the study of bird migration the suggestion was made that the winter quarters of birds might be their ancestral home and that their breeding range is nothing but a seasonal range extension. Though frequently rejected, this theory has been recently revived by Wolfson (1948) and has been used as support for a theory of continental drift. The weakness in his arguments has been exposed by a number of critics (*Science*, 1948) and no specific issue shall be taken with the theory of continental drift. However, the whole theme of bird migration in the Pacific will be discussed, and specifically the question whether or not it can yield any clues to a distribution of land areas in the Pacific that differs from the present one.

Bird Migration in the Pacific

The migrant visitors to the islands of the Pacific can be classed into three groups (excepting sea birds).

A. Northern land birds.
B. Northern shore birds.
C. Birds of the southern hemisphere.

Their histories and routes of migrations differ in various ways. In consequence, each of the three groups will be discussed separately.

A. *Northern Land Birds*

Of the vast horde of land birds that migrate south each fall to southern Asia, a considerable number of species reaches the islands of the Pacific. There is a steady diminution in the number of species as one moves away from the coast of Asia. No less than 120 species winter in the Malay Archipelago (Delacour, 1947), 84 in the Philippines, 38 on Celebes, 24 in the Moluccas, ten in the New Guinea area, and three in the Bismarck Archipelago. These figures fit in very well with the orthodox idea that the northern Asiatic birds winter in the warmer parts of southern Asia and that a certain percentage spills over into the off-lying islands, the fewer the more distant the islands are from Asia. There is absolutely nothing in these figures that would support continental drift.

More important is that most of these migrants belong to genera that are palearctic or holarctic. They are definitely foreign elements in the fauna of their winter quarters. This is particularly evident for the Passerine birds, including such genera as *Anthus*, *Motacilla*, *Monticola*, *Phylloscopus*, *Locustella*, *Acrocephalus*, *Muscicapa*, *Lanius*, and *Sturnus*. The area of their winter range is obviously not their ancestral home. Also interesting is the fact that in some species the tropical populations are sedentary, while the northern ones are migratory.

Among these species are some that are resident in the warmer parts of the Australian region, such as *Falco peregrinus, Alcedo atthis, Eurystomus orientalis,* and *Acrocephalus stentoreus.* If continental drift had been responsible for migration it would be hard to understand why only some of the populations migrate. Rather it fits the concepts of those who consider the current migration phenomena as something recent and exceedingly plastic (Grinnell, 1931).

B. *Northern Shore Birds*

The majority of the shore birds, particularly those that nest in the northern tundras, undertake wide migrations. They are the most conspicuous migrating birds on most of the islands of the Pacific. Furthermore, except for the two swifts, *Chaetura caudacuta* and *Apus pacificus,* they are the only northern birds that winter as far south as southern Australia, Tasmania, and New Zealand. More than 50 species participate in this mass migration, which shows tremendous variation. Some species go only as far south as southern China and Indo-China, others as far as Tasmania and New Zealand. Some hug the coast of Asia closely and merely fan out a little after reaching the Malay Archipelago, while others strike out boldly from Kamchatka or Japan directly south. Finally, some actually cross the open Pacific from America south-westward (see below).

How such migration could be quoted as evidence for the theory that the winter quarters are the ancestral home of a species is inconceivable to me. Species that breed in the same area winter sometimes in very different areas, while species that are found wintering in a given place, for example, New Zealand, arrive there from very different breeding areas, ranging all the way from western Siberia to arctic America. Furthermore, since shore birds are (except for a few ducks) the only migrants on the islands of the Pacific, one would have to conclude that the ancestral population of birds of the Pacific area consisted only of shore birds (and ducks). Actually their present distribution merely proves that shore birds are capable of long transoceanic flights and that for feeding between breeding seasons they have to resort to tidal flats and shore lines.

Even though the migration of the northern shore birds as a whole is easily understood as the immediate product of the special ecology of these birds, still it must be admitted that the migration and the winter ranges of a few species are definitely puzzling. There is, for example, the Bristle-thighed Curlew (*Numenius tahitiensis*) which nests in western Alaska and winters on the coral islands of the central Pacific (Stickney, 1943). Other species are the Pacific Golden Plover (*Pluvialis dominica fulva*) and the Wandering Tattler (*Heteroscelus i. incanus*), of which the greater part of the winter quarters is on the islands of the Pacific. Still others, like the Bar-tailed Godwit (*Limosa lapponica baueri*), cut almost straight south across the Pacific to get to their winter quarters in New Zealand. Finally, there are species, like the Hudsonian Godwit (*Limosa l. haemastica*), which in small numbers and by unknown routes cross from America to New Zealand and southern Australia. On the migration routes of all these birds there are only a few scattered coral atolls where they could rest, feed, and reorient themselves. The hazards of such migration must be tremendous and it seems inconceivable that a migration into or through the central Pacific should have evolved through natural selection if the configuration of land and water had always been exactly the same as today.

C. *Southern Migrants*

The southern land masses (South Africa, Australia), with minor exceptions, do not extend any farther south of the equator than does the Mediterranean area to the north. It is therefore not surprising that the migrations of the birds of the southern continents are on the whole no more spectacular than those of the birds of the Mediterranean. Their subtropical or warm temperate environment does not require an extensive migration. Nevertheless it must be emphasized that there is more migration in the southern hemisphere than is usually realized. Chapin (1931) has shown this well for Africa. It is equally true for the Australian region. In the Moluccas the following Australian birds winter regularly or occasionally (van Bemmel, 1948). All these species have to cross the Banda Sea to reach the islands of the Moluccas.

Falco cenchroides
Falco longipennis
Platalea leucorodia regia
Eurystomus orientalis pacificus
Merops ornatus
Halcyon australasia sancta
Halcyon diops macleayi
Cacomantis variolosus
Chalcites malayanus minutillus
Cuculus pallidus
Eudynamis scolopacea cyanocephala
Misocalius osculans
Scythrops novaehollandiae
Hirundo n. nigricans
Coracina novaehollandiae didima
Grallina cyanoleuca

Much more spectacular are the migrations of the two New Zealand cuckoos, *Chalcites lucidus* (Mayr, 1932) and *Eudynamis taitensis* (Bogert, 1937). The former winters in Northern Melanesia (Solomon Island and Bismarck Archipelago), while the latter winters chiefly in Central Polynesia (Fiji, Samoa), although a considerable number of individuals scatter all across the Pacific from Palau to Tuamotus. Here is a really spectacular migration in two southern hemisphere birds! But again, as in the case of the shore birds that winter in the central Pacific, there is the difficulty of explaining such an extraordinary migration.

THE HISTORY OF BIRD MIGRATION IN THE CENTRAL PACIFIC

There are no essential difficulties in understanding the migration of those species that follow either the continental coasts or chains of islands which are practically in sight of each other. The difficulty lies with species that span large gaps of open water. One would imagine that there must be a high mortality on such flights, and it seems that such flight lines could not be established in the face of natural selection. This objection is particularly grave in the case of such species as the Bristle-thighed Curlew and the Long-tailed Cuckoo that winter on small isolated coral islands.

It cannot be solved without a consideration of the general question as to the origin of migration, which I have discussed previously in considerable detail (Mayr and Meise, 1930). The most natural migration would exist if all birds (of the northern hemisphere) flew either straight south or at least at right angles to the isotherms. That the routes of migration obey this principle only rarely is due to two causes: (1) geographical factors (mountain chains, sea coasts, etc.), and (2) historical factors. The route of migration is originally perhaps always a backtracking of the route of immigration. The four species of palearctic land birds that have crossed Bering Straits to breed in Alaska still cross back across Bering Straits each fall to winter in south-eastern Asia, rather than going south in America with their Alaskan neighbours [Alaska Yellow Wagtail (*Motacilla flava alascensis*), Red-spotted Bluethroat (*Luscinia suecica robusta*), Wheatear (*Oenanthe oe. oenanthe*), and Kennicott's Willow Warbler (*Phylloscopus borealis kennicotti*)]. In reverse, the same is true of the American song birds (*Dendroica coronata* and *Seiurus noveboracensis*) which have crossed from America into eastern Siberia (Anadyrland). On their migration they backtrack their immigration route and winter in the warmer parts of America. Of the birds that have invaded northern Europe from the east, like *Emberiza rustica, Carpodacus erythrinus,* and *Phylloscopus trochiloides viridanus,* most still winter in southern Asia. To get there they have to make tremendously long migrations, whereas suitable winter quarters would be available at a convenient distance due south of their new summer homes.

Even though the original route of colonization may become the first migration route, it is not always possible to determine the area of origin of a migratory bird species from its present winter quarters. Two phenomena are, on the main, responsible for this uncertainty, as pointed out by me previously: route abbreviation and route prolongation (Mayr and Meise, 1930).

(a) *Route abbreviation*: Whenever longitudinal range expansion produces an angle in the route of migration, there is a tendency in many species to cut across the angle in order to reduce the length of the migratory route. For example, if Turkestan had been the original breeding area of the Pacific Godwit (*Limosa lapponica baueri*), from which it migrated to Australia and New Zealand (see below under b.), and if the species had expanded its breeding range from Turkestan to eastern Siberia and Kamchatka, there would be a tendency to migrate from Kamchatka to New Zealand not via Turkestan but directly across the western Pacific.

(b) *Route prolongation*: It is a well-known phenomenon that northern hemisphere species tend to displace their wintering range southward as they expand their breeding range northward. The reasons for this seem to be only in part ecological (crowding in the previous winter quarters). The major reason seems to be physiological. To reach the new breeding quarters a strengthened physiological migratory apparatus is evolved which permits a prolongation of the fall migration unless this is prevented by counter selection. The winter quarters of all birds that winter in the realm of an alien fauna are the result of such secondary route prolongation. This is true for all typically palearctic birds that winter in the Ethiopian, Oriental, or Australian region, and for all typically North American birds that winter in South America. Such prolongation of the migration is particularly evident in the case of those northern shore birds that cross the equator to winter in the subtropics or the temperate zone of the southern hemisphere. All the available evidence (Mayr and Meise, 1930) contradicts the notion that they return to their ancestral home. In the case of some of these species it is even possible that they have become adapted to the cool temperatures and the long days of their breding home to such an extent that it would be advantageous for them to cross the equator rapidly in order to get to a winter home with similar climatic conditions.

The one puzzling point that remains to be cleared up is the location of the winter quarters of a considerable number of species on the isolated and ecologically not very attractive appearing islands of the central Pacific. I have in mind not only the New Zealand Long-tailed Cuckoo but also the various shore birds listed above. If the ornithologist had the assurance of the geologist and paleogeographer that the distribution of land and water in the Pacific area had always been the same as it is today, he would find it difficult to believe that such a migration as that of the Bristle-thighed Curlew could have evolved in the face of the tremendous dangers that the establishment of such a route of migration must have faced. It would be much more convenient if there were evidence for a once-existing, large, now submerged, mid-Pacific continent. Geologists, however, are almost unanimously opposed to such a concept. Rather, the evidence indicates that the Pacific is a very old, quasi-permanent basin. Nevertheless, it is possible that the archipelagos of Oceania had more extensive land areas at one time than they have now. All the recent geological work indicates (for a summary, see Mayr, 1949) that the bottom of the Pacific is sinking rapidly, locally or over wide areas, and that large archipelagos of the configuration of the present Hawaiian Islands have either become completely submerged or exist only as coral "pillars" on top of submerged volcanos. Thus, it seems probable that during various periods of the Tertiary there were not only much larger islands than are found now, but that there were also additional islands and archipelagos where there is now open ocean. The stepping stones leading to the central Pacific were then presumably much more frequent and the land areas of the central Pacific much more attractive. Granting this, the evolution of migration into the central Pacific appears a much less formidable problem.

Orientation During Transoceanic Migration

During the early study of bird migration, it was assumed that, on migration, birds follow very definite routes, almost as fixed as the flight routes of air line companies. This "naive" concept has been discredited rather completely, except for a few special groups of birds such as geese and cranes. Even the "flyways" of ducks, so prominent in the duck hunting literature, are largely a figment of imagination. The flight lines of birds are determined by breeding and winter area, by favourable resting and feeding stations in the intervening area, and by features of the landscape, such as, coastlines, valleys, mountains, etc. Otherwise migration takes place over a broad front. Most of the migration of Pacific winter visitors also seems to proceed on a fairly broad front. However, it is also obvious that there are concentration lines along various geographical features that lead from northern Asia to the Pacific. Such lines are the coast of Asia, China-Formosa-Philippines-Moluccas-Australia, and Japan-Bonin Islands-Marianas-Carolines, Marshalls-Gilberts-Ellice-Fiji-New Zealand. These geographical guide lines seem to be on the main responsible for the concentration of certain species in definite parts of the Pacific, such as the Bar-tailed Godwit (*Limosa lapponica baueri*) on Fiji. On the other hand, they do not entirely explain the existing migration phenomena since some species migrate along the coast of Asia, while others strike out from Japan or even from Kamchatka. There is a definite genetic or traditional element in these migrations. Shore birds migrate usually in flocks, and the easiest solution of the problem of their orientation in the Pacific would be to assume that older, more experienced individuals guide the others to their destination. This in fact may be the right solution but not necessarily so, as is indicated by the case of the New Zealand cuckoos.

These two species migrate individually rather than in flocks, and most of the young birds leave New Zealand in the fall long after the adults have departed (Mayr, 1932). Since these cuckoos are parasitic and their host species are sedentary, it is apparent that these young cuckoos must migrate without any guidance (Bogert, 1937). The Bronze Cuckoo (*Chalcites lucidus*) flies to the Solomon Islands and the Bismarck Archipelago (perhaps touching the Queensland coast), while the Long-tailed Cuckoo (*Eurynamis taitentis*), though coming from the same breeding range, avoids this area and winters mostly in central Polynesia. On the flights necessary to reach these areas, water gaps of a width of 1,000 miles are crossed. Still, the birds find their way on this perilous journey to the winter quarters without a loss serious enough to interfere with their migration mechanism, surely the most miraculous of all feats of avian navigation. Whatever the mechanism of this migration may be, this much is certain that it is much easier to explain if we assume again that the archipelagos of the Pacific had at one time a greater land area than they have now.

Summary

The phenomena of bird migration in the Pacific lend no support to the theory of continental drift. However, the fact that several species winter on small and isolated islands of the central Pacific is consistent with the newer concepts that the insular land areas in the Pacific were formerly more extensive than they are now.

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MOVEMENTS OF PELAGIC SEA-BIRDS IN THE INDO-PACIFIC REGION

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Preliminary Discussion

Ornithologists interested in the movements of marine birds in the Indian and Pacific Oceans must look with envy on the recent detailed work on the migrations of similar species in the Atlantic Ocean. The studies of Wynne-Edwards (1935), Brian Roberts (1940) and Rankin and Duffey (1948) demonstrate the effective manner in which large masses of observational data, made by various observers from time to time, can be utilized in tracing out the seasonal pattern of bird movements and distribution in the oceans. Roberts attempted to apply the method for the Indo-Pacific area in the case of *Oceanites oceanicus* but was forced to admit that

> "scarcity of observations makes it hard to elucidate the migration in the Pacific and Indian Oceans. All the available records were plotted on monthly maps in the same way as for the Atlantic, but so few reliable ornithologists have voyaged in those seas that the information on these maps is too fragmentary to warrant their full publication (1940, p. 184)".

The methods used by the workers mentioned depend essentially on "the accumulated record of small details, compared and checked by many witnesses through long years of watching" (in the words of Dr. T. G. Longstaff, quoted by Wynne-Edwards).

Wynne-Edwards was extremely fortunate in that he was able to short-circuit as it were, the process of accumulating small records by making special voyages across the Atlantic with the financial assistance of the Cunard Line and McGill University; he was able to make eight consecutive trans-Atlantic passages between May and September, 1933, and on each transect made detailed ornithological surveys. Rankin and Duffey were able to take advantage of the unprecedented opportunity of participating in war-time convoys across the Atlantic and contrived to make 28 transects mainly in the period 1943-44 and observations were made every month, except one (February, 1944) from May, 1943, to April, 1944.

For the Indian and Pacific Oceans there are no surveys even remotely approaching the grand scope of these investigations, which will probably remain classics of their kind. The most ample records apply to the north-east Pacific region where the results of many American collecting expeditions (summarized by Bent, 1922, and by Murphy, 1936) provide the main data at our disposal on the wintering grounds and movements of the southern-breeding species. Some records are also available from the near vicinity of Australia and New Zealand, where, however, they are mainly confined to bird lists prepared by observation alone, supplemented in some degree by specimens obtained by beach-drifted material. From the vast area in between, in Oceania and in the Indian Ocean, there is a singular dearth of useful material, even in respect to observations on casual voyages—insufficient in the aggregate, as Roberts found, to be of worth for piecing out the movement pattern of even one species.

It cannot be too strongly emphasized that any precisely obtained and accurate single observation can be of permanent value as a contributing unit towards the preparation of the final picture, and in view of the vast area of our operations—much greater than the Atlantic—and the many species involved—more in number and in general more difficult to identify than in the Atlantic—the fullest use should be made by the serious student of such casual contributions and not be dismissed as possibly due to vagaries of weather, food supplies, etc. Birds with such rigid behaviour patterns as the petrels in respect to their breeding cycle and the extremely narrow range they exhibit in the timing of such processes as egg-laying, etc., cannot be expected to have loose and haphazard links in the remainder of their chain of annual events.

Future Collecting Proposals

Nevertheless, no matter how competent the observer or how excellent the manuals at his disposal for sight identification, I am of the opinion that a fairly extensive programme of specimen collecting must supplement sight observation. The number of species of the all-dark puffinoid petrels, the complex of small *Pterodroma* forms, and the *Puffinus assimilis-lherminieri-gavia* assemblage, cannot be satisfactorily resolved without recourse to the study of specimens.

The time has arrived also when this work should be more systematically organized than it has been in the past. I do not anticipate that exclusively ornithological expeditions will be placed in the field and still less that such opportunities as those of Wynne-Edwards will come the way of most of us. But there are at present in large areas of the Pacific Ocean, either in being or projected, many small government expeditions in connection with fisheries or other surveys whose presence in ornithologically important areas could be usefully capitalized for our purpose at no great cost and with little added burden to the expeditions themselves. The amount of data which could be obtained is dependent of course on the skill of the personnel on board, but in most cases it is unlikely there will be many cases where the persons can either skin a specimen properly or identify it satisfactorily. The position can be met quite well by asking that specimens shot for the purposes of the bird survey be disembowelled and then sun-dried in the rigging, the only essential data (and it must be impressed on the collector that they *are important*) being the colour of the beak and of the legs, date of collection and locality. The specimens are then to be despatched to the ornithological centre concerned in the organization of the scheme. Whatever additional sight observations are to be made, or the nature of the bird log that is kept, must be left to the discretion of the organizers, the capacity of those on board and the time and facilities they have at their disposal. The collection of necessary specimens such as I have indicated is, however, within the means of almost anyone.

TYPES OF DISTRIBUTION AND MOVEMENT IN THE INDO-PACIFIC REGION

Migration and movements of the petrels in these regions have been very thoroughly reviewed by Loomis (1918) and Falla (1934), among others, and they have dealt as fully as it is possible to do with the data available. All that one can attempt at this stage is merely to restate some of their generalizations, with some slight modification, for comparatively little new information has accrued in the meantime.

In a very broad way we can state that two types of movement are exhibited by petrel species—movement in an east-west direction, and movement in a north-south direction. Though the extreme examples of each type of movement are clear-cut and sharply different from each other (cf. *Diomedea exulans* and *Macronectes giganteus* on the one hand and *Oceanites oceanicus* and *Puffinus tenuirostris* on the other) they are to be looked on rather as the extreme manifestations of tendencies which are generally present in petrels in their dispersal movement after the completion of breeding. Thus species which are considered as sedentary show a certain amount of radial dispersion from the breeding centre, in the non-breeding phase, which may be rather diffuse and ill-defined at the centre of distribution but with the character of a decided migration at the peripheral limits. This appears to be the case with *Puffinus gavia* of the Tasman Sea, as will be hereinafter discussed. In other species a tendency to either north-south or east-west movement becomes predominant, but even in extremely developed east-west migration there may be a decided north-south component in the movement as in the case of both *D. exulans* and *Macronectes*—definitely proved in the latter case by the remarkable ringing record of 1948. A species showing highly developed north-south movement, such as *Puffinus tenuirostris*, has, too, a very wide east-west drift as will be indicated in more detail later.

It is also difficult to draw a line between the birds which should be considered "residents" and those which might be ranked as "migrants". Falla, for instance, classes *Puffinus gavia* as a resident in New Zealand, but from the Australian standpoint it can only be regarded as a migrant—(only one breeding region exists for the species—New Zealand). Generally it may be said that birds like petrels, when no longer tied to land by breeding obligations, have the opportunity to wander and the main factors which control these wanderings seem to be availability of food, deteriorating weather conditions in winter and prevailing winds. There is every grade of post-breeding behaviour from local dispersal centring around the breeding islands (typified by such species as *Puffinus pacificus* and *P. assimilis*) to wider dispersals but still with individuals feeding in the vicinity of the breeding islands (as in *P. gavia*), and finally cases where there is a complete evacuation of the seas around the breeding area and the main concentration of the birds is many thousands of miles away. This possibly is only completely attained in the case of those species which breed in very high latitudes, and the seas become absolutely untenable because of rigorour weather conditions. In most other cases, of even extreme trans-equatorial migration, some individuals do not travel far but continue to forage in what might be referred to as "home waters". Thus in *Puffinus tenuirostris* (breeding in south-eastern Australia and wintering in the north Pacific as far as Bering Straits) some individuals are now proved to remain off south-eastern Australia. Similar observations have been made of P. *gravis* and *P. griseus* in the South Atlantic.

There would, therefore, need to be some arbitrary divisions in any scheme of classification of petrel migrants. The following is tentatively suggested as a convenient one for descriptive purposes. The nomenclature is based, with modifications in some instances, on Matthews' *Checklist* (1934).

I. *Sedentary species, with strictly local dispersal after breeding.* These birds occur in climatically congenial areas where the conditions allow residence throughout the year and where the food supply is locally adequate. The dispersal is usually quite restricted, is diffuse, and rarely shows either a pronounced east-west or north-south tendency. The geographical localization of the various breeding communities has resulted in greater sub-specific differentiation than has occurred in the more wandering species.

Some species typical of this category in the Indo-Pacific area are probably:

Diomedea epomophora
Diomedea cauta—only the races *cauta* and *eremita*
Bulweria bulwerii pacifica
Pterodroma melanopus
Pterodroma longirostris (and *pycrofti*)
Pterodroma leucoptera
Pterodroma cookii
Pterodroma hypoleuca
Pachyptila turtur
Pachyptila crassirostris
Pachyptila vittata
Puffinus assimilis
Puffinus lherminieri
Puffinus pacificus
Pelagodroma marina
Pelecanoides spp.

II. Wandering species, showing definable migratory movements to and from their breeding islands covering long distances, though some individuals may remain in their near vicinity throughout the year.

IIa. Species in which the north-south component of the dispersal movement is predominant, often being trans-equatorial in scope.

(a) Northern breeders, e.g.
  Puffinus leucomelas
  Puffinus creatopus
  Puffinus opisthomelas

(b) Southern breeders.
  Pterodroma inexpectata

Puffinus carneipes
Puffinus tenuirostris
Puffinus griseus
Puffinus bulleri
Oceanites oceanicus

IIb. Species in which the east-west component of the dispersal movement is predominant, and the extent of this, in some cases, is so considerable that the movement becomes circumpolar, e.g.

Diomedea exulans
D. melanophris
D. chrysostoma
D. chlororhyncha
D. cauta salvini
Phoebetria palpebrata
Phoebetria fusca
Macronectes giganteus
Daption capensis
Fulmarus antarcticus
Thalassoica antarctica
Pterodroma lessonii
Pterodroma lugens
Pterodroma mollis
Halobaena caerulea
Pachyptila salvini
Pachyptila desolata
Pachyptila belcheri
Procellaria aeqinoctialis
Procellaria parkinsoni
Procellaria cinera
Puffinus gavia—restricted; possibly should go in Section I.
Fregetta grallaria
Fregetta tropica.

East-West Migration

Most of the data we possess of this movement is observational and consists of sight observation of individuals of species at sea, whose known breeding islands are far distant, and supported also by the discovery of beach-drifted remains on lee shores. In the Australian and New Zealand region most of such records refer to species which breed on islands to the west, including Amsterdam and St. Pauls Islands, the Crozets, Kerguelen and Heard Islands.

There are in support of extensive east-west migrations four records of ringed birds as follows:

Diomedea sp. Marked by shipwrecked sailors at the Crozets I. on August 4, 1887, and recovered near Fremantle, Western Australia on September 18, 1887, i.e. 46 days later, 3,000 miles to the eastward (Serventy and Whittell, 1948, p. 107).

Diomedea exulans.

(a) Marked by a whaling vessel on December 8, 1847, in Lat. 43° S., Long. 148° 40′ W. and shot on December 20, 1847, in Lat. 45° 56′ S., Long. 78° 27′ W. (off the coast of Chile), i.e. 12 days after marking, 3,150 miles eastward (Murphy, 1936, p. 546).

(b) Ringed at Kerguelen, while nesting, on December 21, 1913, and recaptured at Lat. 56° 10′ S., Long. 78° 04′ west of Paris (near Cape Horn) on December 19, 1916 (Murphy, 1936, p. 546).

Macronectes giganteus. A bird ringed as a fledgling at Signy I., South Orkney Islands on March 20, 1948, was recovered at Fremantle, Western Australia, on July 10, 1948 (Serventy, 1948).

The last two records point strongly to circumpolar flights being involved and support the views of Dixon (1933) and of Murphy (1936, p. 547) that Wandering Albatrosses may circumnavigate the world in the west-wind zone. The *Macronectes* record adds weight to these opinions and it may be that several of the species inhabiting the higher latitudes in the west-wind zone are directed in their movements by the prevailing wind and circulate constantly in a west to east direction. How general such a movement is cannot be stated on present knowledge and must await further ringing investigations.

Attractive though the circumpolar flight theory is, it is doubtful on present knowledge of petrel occurrences in the southern seas whether all or even most species partake in it, despite my recent over-zealous comment on the subject (Serventy, 1948, p. 158). Thus not all the southern petrels have a continuous pelagic distribution in the south. *Diomedea chlororhyncha* for instance, though it ranges widely in the Atlantic and in the Indo-Pacific region to as far east as New Zealand is not found in the eastern Pacific where it appears to be replaced by *Diomedea bulleri* (Murphy, 1936). *Procellaria parkinsoni* ranges only in the Pacific and is rare, apparently, in the Tasman Sea to Australia. Birds which do not complete the circuit of the globe must, however, face considerable difficulties on the return flight to their breeding islands and one sometimes wonders whether some of the spectacular records of east-west flight (or swimming in the case of penguins, see Serventy and Whittell, 1948, p. 64) relate to birds which have been driven so far eastward that it is problematical whether they are physically capable of returning.

These circumpolar movements in the prevailing west-wind belt call to mind the unorthodox migration theories of Commander Bernard Acworth in his extraordinary book "This Bondage" (1930), in which he insisted that bird migration was solely due to and wholly controlled by wind drift. It would appear that his theory may have application at least to these circum-polar petrels (see also below).

It has been stated earlier that even with these petrels showing east-west movements there is a subsidiary north-south component in the general movement and many species which breed in the Antarctic and Sub-Antarctic Zones approach Australian and New Zealand shores (i.e. into the Sub-Tropical Zone) in the winter months. In areas where the convergences trend northerly this move is still more pronounced and some individuals of certain species may even cross the Equator. Murphy (1936) gives a number of instances. Among those which range far northwards along the west coast of South America and cross the Equator at times are *Fulmarus antarcticus* and *Daption capensis*.

The case of *Puffinus gavia* has previously been briefly alluded to. As far as is known at present its breeding range is confined to New Zealand, but it occurs as a wanderer both east and west of New Zealand.

The furthest east records are those reported by Murphy (1930), specimens collected east of the Chatham Islands in Lat. 42-44° S., Long. 173-175° W. in January. This position is about 800 nautical miles east of New Zealand. The furthest west record is of a beach-drifted bird found at Bunbury, Western Australia, in April, 1937, about 3,500 nautical miles west of New Zealand (Serventy, 1939). The species, however, occurs commonly in South Australian waters in spring and summer as well as the winter, and this is the case also along the east Australian coast between northern Tasmania and Hervey Bay in central Queensland. Both of the races partake in the movement, the nominate race in the north and east coasts, and the larger *huttoni* in the south. Apparently the summer birds are immatures or non-breeding adults.

This east-west trans-Tasman migration is paralleled by two other New Zealand species. The White-fronted Tern (*Sterna striata*) reaches Australia in the winter and extends from Queensland in the north to South Australia in the south-east. As far as is known no individuals "summer" in Australia and the migration is thus more clear-cut than in the case of *P. gavia*. The third such migrant is the Double-banded Dotterel (*Charadrius bicinctus*) which is mainly a winter visitor also but some individuals stay over in the summer. It occurs mainly in the south-eastern corner of the continent, including Tasmania, but with a lesser penetration north to Queensland and west to Perth in Western Australia.

North-South Migration

The bulk of north-south migration is of southern breeding species which during the southern winter and the northern summer disperse northwards after the breeding cycle is over. In contrast to six trans-equatorial migrating petrels which breed in the south there is only one northern breeder which makes a trans-equatorial movement southwards (*Puffinus leucomelas*) and that one barely crosses the Line.

The Movements of Puffinus tenuirostris

The C.S.I.R.O. has recently undertaken a study of one of the trans-equatorial migrants of the Pacific, *Puffinus tenuirostris*, whose breeding grounds are confined to south-eastern Australia (from Gabo Island in the east to St. Francis Island, off Ceduna in South Australia, and on islands all around Tasmania). There is no evidence of any kind to suggest that it breeds elsewhere. Therefore, because of its restricted breeding area, combined with its huge distribution range in the Pacific, it is a peculiarly suitable species to study migrations as compared with, say, *Puffinus griseus* or *Puffinus carneipes*, which have several distantly separated breeding grounds. *Puffinus bulleri*, another trans-equatorial migrant, is similarly suitable, but as it appears to be much fewer in numbers than *P. tenuirostris* the accumulated data so far is very much less. One important disadvantage of *P. tenuirostris* is that it is so similar in superficial appearance to a number of other all-dark petrels that it does not lend itself readily to sight identification at sea.

A ringing programme has been instituted on *P. tenuirostris* since March, 1947, a programme which is designed primarily for population studies and only incidentally for migration. However each year numbers of ringed birds are added to the pool of marked birds ranging in the Pacific and eventually we trust that some of them will help in unveiling the story of the movements of the species. So far about 1,500 birds with copper rings on their legs are believed to be at large. Up to the present, no evidence bearing on movements has been brought to light as a result of the ringing programme.

However the general plan of the species' distribution and movements can be indicated on the evidence of specimens collected throughout its wide range. Particulars of these have already been published by Bent (1922), Loomis (1918), Murphy (1936) and others, and I am indebted to various museums for details of subsequently collected specimens.

This species was described independently from the two extremes of its range—by Temminck as *Procellaria tenuirostris* from Japan in 1835 and by Gould as *Puffinus brevicaudus* from Bass Strait (Green Island) in 1847. Though Schlegel (1863) suggested that the two might be one species, Coues (1864, p. 127) and Gould (1865) continued to regard them as separate. Gould mentioned the seasonal absence of the birds but did not commit himself as to their migratory movements in any way. Montgomery (1898) thought they migrated southwards. However, A. J. Campbell (1901, p. 882) drew the conclusion accepted by most ornithologists since that really one species is involved, and that after breeding in the north it migrates into the Pacific as far north as Japan and as far east as Samoa. Later information enables us to extend these limits to Alaska and Bering Straits and the North American coastline. Curiously, however, there are ornithologists who adhered, until recently, to the belief that two species exist, that extensive migrations do not occur and that in the non-breeding period the birds merely disperse into local waters adjacent to the breeding islands (Mathews, 1912, vol. ii: Mathews and Iredale, 1915). Iredale still retains this view (personal communication).

From the evidence of specimens the sequence of events in the *exodus-migration*, as Loomis terms it, is as follows. Young and adults leave the breeding islands at the end of April and the beginning of May. Dead birds, including young with traces of down still adhering to the feathers, have been picked up on New Zealand beaches during late April and May. None, however, are found on east Australian beaches at this time excepting in South Australia, when dense flights of shearwaters are seen flying south-eastwards following the shoreline into, apparently, Bass Strait.

Further out in the Pacific *April* specimens are known from the Marshall Islands and Bering Island; *May* specimens from the Bonin Islands, Japan and Alaska; *June* specimens in great plenty from Japan and particularly Alaskan waters; *July*, *August* and *September* from the Bering Straits-Alaska region, penetrating even into the southern portion of the Arctic Ocean (Kotzebue Sound). In *October* still a few specimens are collected in Alaska and for the first time a few appear in California (Monterey Bay); there is also one skin from the central Pacific (10° N., 168° W.). During *November*, *December* and *January* considerable numbers have been taken along the Californian coast, with the peak in December. (See Fig. 2.) There is also a December specimen from Low Archipelago (Tuamotus), another from Tanna in the South Hebrides, and two from seas on the west of New Zealand (37-38° S., 179° W.). From the third week in September,

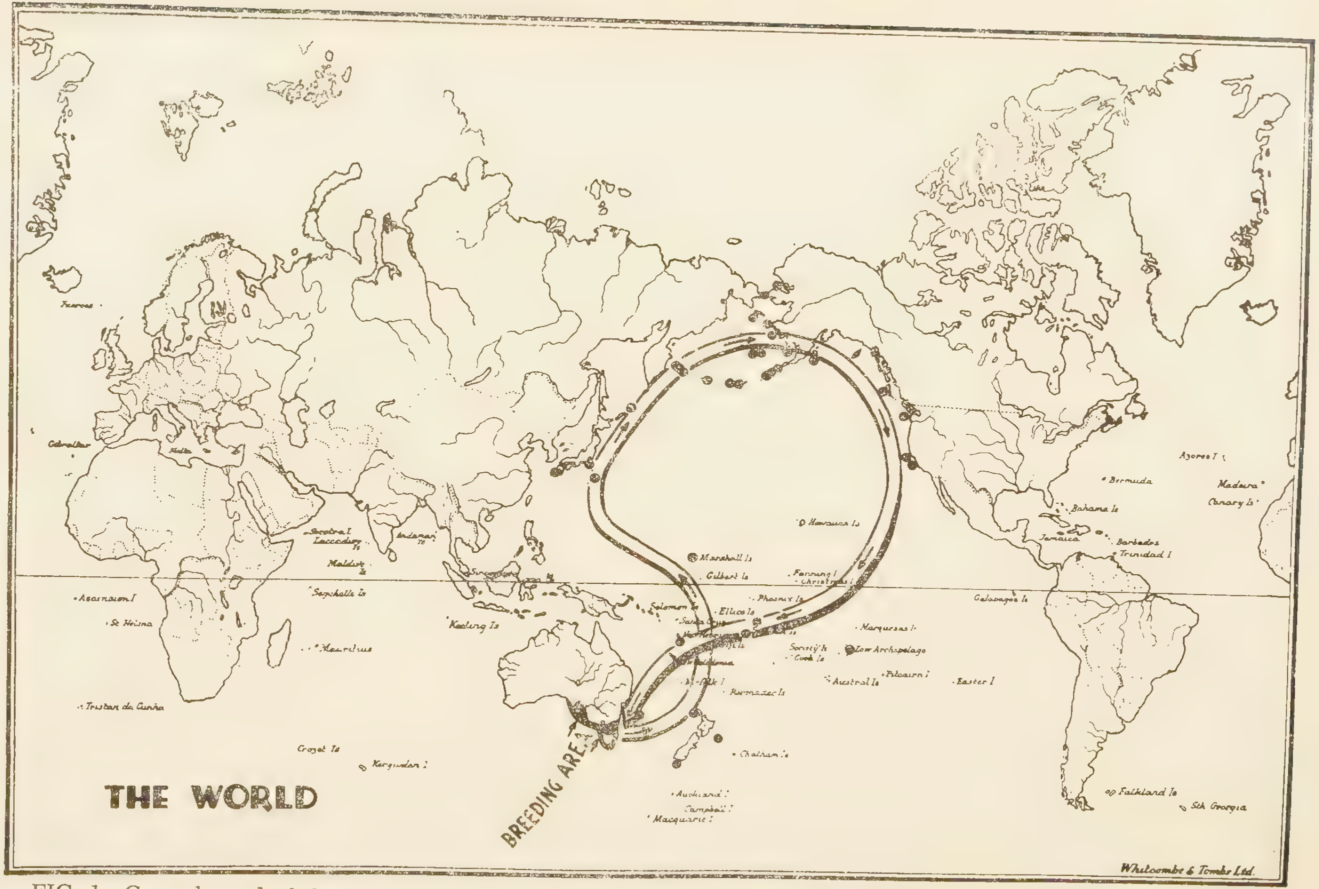
THE WORLD
BREEDING AREA
Faeroes
Gibraltar
Malta
Socotra I
Laccadive Is
Maldive Is
Andaman Is
Seychelle Is
Ascension I
St Helena
Mauritius
Tristan da Cunha
Crozet Is
Kerguelen I
Keeling Is
Solomon Is
Santa Cruz
Ellice Is
Marshall Is
Gilbert Is
Phoenix Is
Fanning I
Christmas I
Hawaiian Is
Fiji Is
New Caledonia
Norfolk I
Kermadec Is
Chatham Is
Auckland I
Campbell I
Macquarie I
Society Is
Cook Is
Marquesas I
Low Archipelago
Austral Is
Pitcairn I
Easter I
Galapagos Is
Bermuda
Bahama Is
Jamaica
Barbados
Trinidad I
Azores I
Madeira
Canary Is
Falkland Is
Sth Georgia
Whitcombe & Tombs Ltd.

FIG. 1.—General trend of the migratory path of *Puffinus tenuirostris* as deduced from localities of museum specimens (indicated by heavy dots).

throughout October and tailing off through November to December, dense flocks are seen flying south along the east Australian coast. During this period a certain amount of mortality may occur, varying from year to year. In some seasons deaths among the migrating shearwaters may be of catastrophic proportions.

This phenomenon which in some respects may be likened to the celebrated "El Nino" mortality in Southern South America (Murphy, 1936, p. 101) appears to be due to starvation. It is also a phase of the *P. tenuirostris* investigation which is being studied by the C.S.I.R.O., and we have found, among other things, that there is a striking correlation with pelagic fish abundance. There is, for instance, a dearth of Southern Bluefin Tuna (*Thunnus maccoyii*) when the bird mortality is high. The link between the birds and fish is undoubtedly through the common food supply—they both feed on the same organisms: Euphausiids, cephalopods, anchovies, and other surface fish. It appears that during the migratory period whilst the birds are moving south in dense aggregations there is a heavy demand all round on the same stock of food and when this is in minimal supply in some years both birds and fish are adversely affected. The basic causes, involving hydrological and plankton studies, have yet to be worked out.

From this fairly considerable though still very inadequate body of facts we can infer that *Puffinus tenuirostris* migrates on its exodus movement eastwards across the Tasman, deploying north and, though avoiding Australian, New Guinea and southern Asiatic waters, trends westerly in the north Pacific, approaching Japan as it moves northwards to Bering Straits and Alaska. Here is the climax of the movement. On the return migration, it appears that a different course is followed, trending through the eastern Pacific, when the fringe of the migration touches the British Columbian, Oregon and Californian coasts. There must be a swing westward in the mid-Pacific as the September movement along the east Australian coast has been noted as far north as central Queensland (Capricorn Is.). Apparently, the birds strike the Australian coast *en echelon* but both skins and sight observations bearing on the mid-Pacific phase of the return migration are deplorably scanty.

The movement, as thus outlined, is thus not wholly unlike that in the Atlantic of the Greater Shearwater (*Puffinus gravis*) as determined by Wynne-Edwards, and of *Oceanites oceanicus* as worked out by Roberts—insofar as we can compare them on the imperfect evidence available. Wynne-Edwards states there is a sort of circulation of Greater Shearwaters in the North Atlantic in the same direction as the circulation of the surface water of the ocean itself. He appears to look askance at the suggestion that this may be correlated with the movements of plankton and inclines to the view that it might conceivably be due to a drift in the direction of the prevailing westerly winds (1935, p. 260). Here again is an instance when Acworth's wind-control theory of bird migration may have some application (see above).

We might glance briefly at the interesting movement southwards along the Washington-Oregon-California coast in October-January. Fig. 2 is a frequency-time distribution graph of the California-taken specimens of *Puffinus griseus* and of *Puffinus tenuirostris* enumerated by Loomis (1918, pp. 134, 139). It will be seen that *P. griseus* shows a bi-modal curve, with the peaks in May and September, representing the height of the exodus and return-migrations respectively. *P. tenuirostris* on the other hand, shows only a single-peaked curve, with the peak in January. The curious thing about the latter is that not only is the return-migration much later than that of *P. griseus* but that it occurs at a time when the species is in full-breeding activity at its only known nesting islands. Loomis offered the explanation that the irregularity in their occurrence in California and their late appearance created a doubt whether they were really returning migrants bound for an unknown South American breeding station or whether they were strays that had missed their way and, falling in with the rear-guard of *P. griseus,* had come down the wrong coast, the American instead of the Asiatic (Loomis, 1918, p. 138).

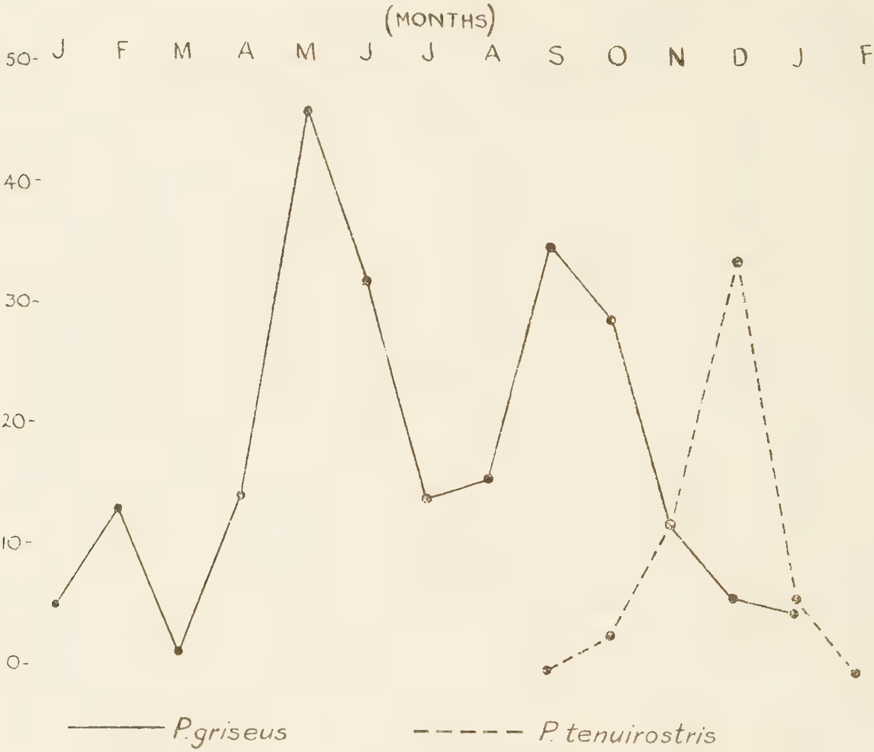

FIG. 2.—Frequency-time distribution of California-taken specimens (data from Loomis, 1918, p. 134).

P. griseus breeds on the southern portions of both the western and eastern Pacific and the northward and southward migrants passing California could be either the western or eastern populations, or both. It is impossible to say which at present and, as Murphy has shown (1936), there is no taxonomic difference discernible within the species. The fact that there is no evidence of an exodus-migration of *P. tenuirostris* along the California coast, as there is with *P. griseus,* strongly suggests that the former species does not breed in the South American section of the Pacific.

It may be true, as Loomis suggests, that these California-taken specimens of *P. tenuirostris* are lost birds which have missed their way. Murphy also accepts this explanation (1936). They are certainly non-breeders. They may be examples of those individuals of the species which Wynne-Edwards would consider are skipping a nesting season or they may be immatures. In either case they may be leisurely circulating in the north Pacific, following the general course of migrating shearwaters, but probably considerably more eastward than that taken by the breeding birds.

There is one observation from the eastern Pacific which on the views expressed above, appears anomalous. Hallinan (1934, p. 306) reports collecting one bird, out of several floating in the tepid water, at Naos Island in the Panama Zone on June 8, 1915. At this time of the year, the birds should be in the western, not eastern, Pacific. The record needs re-examination.

It had formerly been thought that *Puffinus tenuirostris* entirely evacuated the Australian area during this winter migration. That this is not entirely so was first proved on July 24 last year (1948) when Mr. K. A. Hindwood and party found eight specimens on the beach at Cronulla, New South Wales, together with one of *P. griseus*. The weather had been extremely rough the previous week and associated with the *Puffinus* remains were also 46 prions — these are the normal victims of winter gales. This is the first time that either *P. tenuirostris* or *P. griseus* has been found on these beaches after winter storms, and it would indicate that the species do not remain in any great strength in normal years in the Tasman Sea.

The foraging range of the species whilst it is breeding may be given some attention. The westernmost recorded limit is Bedford Harbour near Hopetoun, Western Australia, which is about 750 miles west of the furthest west breeding island (St. Francis Island). In the east birds have been washed ashore in New Zealand, about 1,200 miles away. These distances are not excessive in view of Lockley's findings on *P. puffinus*, whose incubation period shift is up to 7-10 days and ringed breeding birds have been known to forage 600 miles (1942). The incubation period shift of *P. tenuirostris* is much greater, being 12-14 days. Therefore it could conceivably have a much greater cruising radius.

Other Species

I have not sorted out the evidence yet on other trans-equatorial migrants which probably have the same pattern as *P. tenuirostris*. I have referred to the fact that of all of them probably the movements of *P. griseus* will be most difficult to disentangle, because of the number of its wide-flung breeding grounds.

P. bulleri, the New Zealand breeder, may have a regime approximating to *P. tenuirostris*, and it is rather interesting that the California records all occur at the same time of the year as those of *P. tenuirostris*.

P. carneipes is an interesting case. The definitely known nesting areas are in south-western Australia, Lord Howe Island and around the North Island of New Zealand. Wintering migrants, presumably from Western Australia, have been taken in the Indian Ocean as far west as Ceylon but whether these also penetrate into the North Pacific is unknown. There is a suggestive difference between this species and both *P. tenuirostris* and *P. bulleri* regarding its occurrence off California.

Specimens have been taken in the February-September period as well as later in the year, and it is thus similar to *P. griseus* in its occurrences in this sector, though in very much lesser numbers. This suggests that possibly *P. carneipes may* have a southern South American breeding place – unless its migratory regime is different from that of both *P. tenuirostris* and *P. bulleri.*

Unlike *P. griseus, P. carneipes* does appear to exhibit slight racial differentiation, in respect to measurement characters, in the different nesting colonies (Hindwood, 1945, p. 246). The matter requires further study and if the existence of the difference is substantiated it should be possible to assign to their breeding grounds at least some of the specimens collected at sea.

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DISCUSSION

Dr. Falla mentioned his examination of specimens of *Puffinus tenuirostris* from the coast of North America, of which at least 90 per cent. were immature birds and non-breeders.

Dr. Murphy emphasized the point made by the speaker that the great oceanic migrations of sea birds are all prevailingly peripheral. Even *Puffinus gravis* which breeds on a small island in the South Atlantic is a coastal or off-shore bird on the east coast of America during migration. We know from many crossings that such birds are not abundant in the central regions of the Atlantic Ocean.

The term latitudinal is perhaps better used for migration across the parallels, and longitudinal for passage across the meridians. It might be desirable to find some other terminology to prevent confusion.

Dr. Murphy said that the outer islands of Tierra del Fuego constitute one of the least known areas in the world for breeding sea birds, with reference to Dr. Serventy's suggestion that *Puffinus carneipes* may breed in this area.

Dr. Austin asked whether any evidence was available as to how old these petrels are when they breed. Dr. Serventy replied that this had not been established but he considered that it would certainly not be in the first year.

Dr. Austin further commented that birds of the year are very frequently cast up on beaches and that in terns especially, young birds remain on the wintering grounds for the first year. Such immature birds may account for the double peaks in wintering populations represented graphically by Dr. Serventy.

SYMPOSIUM ON MARINE BIOLOGY IN THE PACIFIC BASIN, WITH SPECIAL REFERENCE TO FISHERIES

THE FISHERIES RESEARCH BOARD OF CANADA – ITS ORGANIZATION AND PROGRAMME

By W. A. Clemens, Department of Zoology, University of British Columbia, Vancouver, B.C., Canada

The Biological Board of Canada is a rather unique organization and has had an interesting history.

In 1894 Professor E. E. Prince, soon after his appointment as Dominion Commissioner of Fisheries, urged upon Sir Charles Tupper, then Minister of Marine and Fisheries, the establishment of a marine laboratory. In the following year, Professor A. P. Knight brought the matter before the Royal Society of Canada which society consulted with the British Association for the Advancement of Science and this led to the naming of a Biological Station Committee consisting of prominent British and Canadian biologists. This Committee prepared a memorial which was presented to the Canadian Government in 1898. Its representations included:

(a) That there was need for thorough knowledge of the life-histories of marine animals and nature and source of the food supply of fishes.

(b) That the scientific work of the Station be done by experienced investigators connected with the various Canadian Universities.

(c) That while the Station should be a Government institution, the administration should be vested in a special board consisting of one or more representatives from the Department of Marine and Fisheries and one representative from each of the Universities represented in the delegation.

(d) That an appropriation of 15,000 dollars be made, of which 5,000 dollars be applied to construction and outfit and 10,000 dollars to maintenance for a period of five years.

The Government looked upon these representations with favour and in 1898 came into being the Biological Board of Canada, now known as the Fisheries Research Board of Canada.

Professor Prince was named Director of the Station. The laboratory was completed in June, 1899, at St. Andrews, N.B. It was approximately 15 feet x 50 feet and so constructed that it could be placed on a scow and towed from place to place. In 1908 a permanent building was erected at St. Andrews.

The Pacific Biological Station at Nanaimo was established in 1908 following earnest representations made to the British Columbia Fisheries Commission by the Rev. Geo. W. Taylor, who became the first Director.

Thus there came into being the Biological Board of Canada and its two Biological Stations. In 1924 and 1925 there were established the two Fisheries Experimental Stations, one at Halifax, N.S., and one at Prince Rupert, B.C., for the investigation of problems connected with the processing of fishery products. Since then there have been added two more stations, one an Experimental station on the lower St. Lawrence river and the other a Biological station at Winnipeg, Man.

The purpose of this historical introduction is to indicate that the Biological Board is a relatively old institution and that its beginnings were very small and humble. It has survived and developed because it has done useful work. Few organizations, if any, have had a greater influence in the development of research in Canada than has the Biological Board. It has drawn to its problems many of the very best trained biologists in Canada. It has interested the Universities in marine problems and has given them a field for study and research. This has undoubtedly contributed to the breadth and quality of biological instruction in the Universities and has provided an opportunity for the young men and women to become acquainted with marine biological problems and to obtain experience in research.

The Fisheries Research Board has thus reached its fiftieth anniversary. It began in a small way with a 5,000-dollar building and an annual appropriation of 2,000 dollars. Today it has six stations whose laboratories and associated buildings and equipment have a value of perhaps 500,000 dollars, and it has an annual appropriation of approximately 750,000 dollars. While it originally carried out its investigations by voluntary workers, it now employs about 70 full-time scientists, about 70 temporary summer investigators, and probably 70 non-scientific persons as typists, field-men, boat crews, etc.

As stated previously, the Board was first administered by one or two representatives of the Department of Fisheries and one representative from each of the Canadian Universities interested in marine and fishery problems. About 1923, provision was made for representation from the fishing industry and at present there are two such from each coast. The present constitution of the Board consists of two representatives from the Department of Fisheries, four from the fishing industry and nine from Universities.

This Board is responsible to the Minister of Fisheries and is essentially the scientific division of the Department. However, it administers its affairs, including the expenditure of its grant, as an independent body. It makes its appointments upon the approval of the Minister and thus its employees are not civil servants, although they come under certain general government regulations.

By this arrangement, fisheries research is directed by experienced men in administration, outstanding men in the fishing industry and prominent men in the various branches of science. Altogether this has proved to be a very desirable and advantageous arrangement.

The Board meets annually in Ottawa, usually in a 7- to 10-day session in early January and usually the Minister of Fisheries and the Deputy-Minister attend some of the sessions.

At these meetings the Directors of the Stations present reports on the work of the year and make recommendations. The Board reviews these, discusses programmes and problems, lays down policies, and deals with numerous matters which come up in connection with its widespread and diversified work.

An Executive Committee of seven members, two of which are repersentatives of the industry, deals with matters which require attention during the year, meeting three or four times or oftener if necessary. In addition there are four sub-Executive Committees which deal with matters of local concern – one on the Atlantic coast, one in Quebec, one in the mid-west, and one on the Pacific coast.

There is thus a rather efficient system for dealing with the work which is widespread geographically and which is diverse in character. Shortcomings, if any, in the Board's operations are due to failure on the part of members to carry out their duties and not to the basic principle of the organization.

THE PACIFIC BIOLOGICAL STATION

The Pacific Biological Station was opened in 1908 with the Rev. George W. Taylor as Director. In the early days of the Station attention was given chiefly to the collection and identification of marine plants and animals. This was natural and logical for little was known of the life of these waters, even of the fishes. Studies of herring and salmon were initiated and observations made on a number of other fishes. The Director was the only permanent appointee and University personnel was depended upon for the carrying out of investigation during the summer months.

In the early days, too, the problem of conservation of the fishery resources was not acute, for fishing intensity was not very high. However, during the First World War the fishing effort increased greatly and by 1924 the time was ripe for concentrated investigations of fishery problems and therefore for year-round investigators. So in rather rapid succession approximately ten appointments were made to the permanent staff. The investigations of the Station have been rather extensive, covering various phases of the salmon, pilchard, herring, dogfish and shellfish fisheries. Fish cultural operations have received a great deal of attention and a fairly steady programme in oceanography has been maintained.

PACIFIC FISHERIES EXPERIMENTAL STATION

About 1922, the Department of Fisheries decided that the work of the Fisheries Research Board should be extended in other directions. One suggestion was that there should be established on each coast a School of Fisheries. However, after very careful consideration it was decided that the first need was for investigations which would lead to better methods of handling and processing of fish. As a matter of fact information in this regard was needed before teaching could be effective. Provision was made, therefore, for the establishment of two technological stations, to be called Fisheries Experimental Stations, one on each coast.

The Pacific Fisheries Experimental Station was established at Prince Rupert, B.C., in 1924. Work was commenced on refrigeration problems and a little later studies on fish oils and meals were initiated.

Subsequently, investigations were extended to various problems connected with canning, smoking, production of vitamins, production of by-products, and many other phases of the fishing industry.

During the Second World War, the Station buildings at Prince Rupert were required for war purposes and so the station was re-established in Vancouver.

THE ATLANTIC BIOLOGICAL STATION

As stated previously, work was begun on the Atlantic coast in 1898 with the construction of a movable laboratory. In 1908, the Biological Station was established at St. Andrews, N.B., and has continued there up to the present time.

In the early days, the programme of this Station followed along much the same lines as those of the Nanaimo station. Its chief fishery investigations have been concerned with shad, cod, herring, mackerel, smelt, Atlantic salmon, trout, lobsters and oysters. Oceanography has also had a prominent place in the Station's programme.

ATLANTIC FISHERIES EXPERIMENTAL STATION

This station is the counterpart of the Fisheries Experimental Station in Vancouver. It was established in 1923. One of its first undertakings was the development of ice fillets. Much attention has been given to refrigeration, smoking and salting of fish, to fish reduction processes, and to fish spoilage.

GASPE FISHERIES EXPERIMENTAL STATION

Because of the peculiar problems of the fisheries in the lower St. Lawrence River, the Gaspe Experimental Station was established in 1936 at Grand River. As a result of studies, improvements have been made in the lay-out of the fishing vessels, improved methods devised for cod liver oil production and for smoking and salting fish.

CENTRAL FISHERIES RESEARCH STATION

The Central Fisheries Research Station was organized in 1944 in Winnipeg. Its major problem has been a study of the white-fish and tullibee infestation by the larval stages of the tapeworm, *Triaenophorus crassus*. Experiments are being carried out to determine if drastic reduction in the numbers of pike, *Esox lucius*, which carry the adults of the tapeworm, will reduce significantly the occurrence of the cysts in the whitefish and tullibee.

The Station has also commenced a study of the goldeye, *Amphiodon alosoides*, which has become greatly reduced in numbers and an investigation of ciscues.

The Board has given assistance to the Prairie Provinces in the technological field and has loaned a member of the staff of the Vancouver Station for help with various problems in Manitoba, Saskatchewan and Alberta.

NORTHWEST TERRITORIES

In 1944 the Board was requested by the Department of Fisheries to undertake fishery surveys in the Northwest Territories to obtain definite information as to the fish resources in the far northwest. In that year parties were sent to Great Slave Lake and the lower Mackenzie River. In 1945 parties operated on Great Slave Lake, Great Bear Lake and in the Yukon. Since then investigations have been continued on Great Slave Lake and other lakes in the northwest area under the auspices of the Winnipeg station.

NORTH-EAST ARCTIC

Recently the Fisheries Research Board has undertaken investigations in the north-east Arctic region with the objective of determining the fish resources and how best these may be made available to the native populations.

Co-operation

The Fisheries Research Board co-operates with various agencies for the advancement of fisheries researches as follows:—

(a) On the Atlantic and Pacific Coasts with the Department of National Health in a study of shellfish poisoning;

(b) With the Atlantic Provincial Governments and the Government of Newfoundland on a herring investigation;

(c) With Nova Scotia authorities in trout, salmon and clam studies and collection of fishery statistics;

(d) With the British Columbia Research Council in fish net preservation and in seaweed investigations;

(e) The Provincial Fisheries Department of British Columbia has contributed financial support to the pilchard, herring, oyster and clam investigations.

The Board also co-operates with several National Bodies:—

(a) The Canadian Committee on Freshwater Fisheries Research;

(b) The Canadian Committee on Food Preservation sponsored by the Board, the National Research Council and the Department of Agriculture;

(c) The Joint Committee on Oceanography, sponsored by the Board, the National Research Council and the National Defence Board.

The Board is represented on the Food and Agriculture Organization of the United Nations.

Publications

The results of the researches of the Board are published in various ways:—

(a) Final scientific and technical papers are published in the Journal of the Fisheries Research Board.

(b) More popular or special reports are issued as bulletins.

(c) Some papers are published in various scientific journals and reprints obtained for distribution.

(d) Progress reports are issued by the Atlantic and Gaspe Stations and by the Pacific Station.

(e) An annual report is published.

(f) Comprehensive systematic papers are published in a Faunal Series.

The Board is thus carrying forward a very extensive programme, consisting of specific investigations which may have early application, of long-term projects which may have postponed application and of fundamental researches which must form the basis for sound advance in fishery science.

Discussion

To Professor Yonge's request for more information on the faunistic record work, Professor Clemens answered that progress was slow. In the early days there was considerable accumulation of information about fauna, but records were interrupted by World War I and the depression, though a series of publications had been issued, e.g. three, by Wailes, on Protozoa.

FISHERIES RESEARCH ON THE CANADIAN PACIFIC COAST

By R. E. Foerster, Pacific Biological Station, Fisheries Research Board of Canada, Nanaimo, B.C.

Biological fisheries research on the Canadian Pacific coast in recent years has been directed largely to studying the life-histories of the various species of economic importance and the reaction of the populations to present fishing effort and intensity. The objective has been to determine the state of each fishery, its general trend and to ascertain what measures might be taken, if and when necessary, to so regulate or "manage" the fishery that it can enjoy maximum exploitation on a sustained yield basis. If by the term "conservation" one means "wise use", we are striving to establish suitable and effective principles of conservation for all our fisheries.

It is extremely doubtful whether establishment of management policies designed to provide a more or less uniform yield each year is possible. However, desirable from the point of view of stable commercial production and marketing, the fact must be faced that we are dealing with dynamic biological populations subject to many varying and uncontrollable factors which have both long-term cyclical or short-term seasonal influences. The best that may be achieved perhaps is to remove the highly fluctuating short-term variations and to predict the long-term trends. For our own fisheries our accumultaion of accurate statistics with which to trace and define cyclic trends is yet far too meagre. We can only keep clearly in mind their likely occurrence, meanwhile tackling the more immediate problems of reducing those short-time fluctuations in production and abundance which are in some measure controllable or considering for adoption such regulations as may, with present knowledge, lead to a stable and sustained fishery.

The fact is too often overlooked that for our marine and anadromous fish populations the ocean is primarily a nursery and feeding basin, only certain areas of which are highly productive. These have unquestionably a limited feeding capacity and under normal naturally-balanced conditions they are now fully utilized. It is difficult to conceive of any areas naturally unutilized, virgin feeding grounds, as it were. There may be some, however, which through catastrophe, calamity or other abnormal circumstance may be temporarily barren of normal fish populations and hence regions open for expansion by others.

In the ocean, therefore, as in a lake, there exists a dynamic balance of Nature, continually changing as pressures of populations vary and as environmental conditions fluctuate. In studying fish production, consequently, we are in reality studying the inter-relationships of populations and unless the study be sufficiently comprehensive, the fundamental or basic factors influencing production of the species being investigated will remain obscure and unknown. As certain fisheries wax and wane in cyclic rhythm, as some commercially important species experience the influence of fishing drain while others remain untouched, the natural balance may completely change and have a most marked effect on those species of importance to us. For some years there existed off the west coast of Vancouver Island a rather important fishery for pilchards during the summer months. For the past three years this fishery has been virtually non-existent, due in part, to failure of new age-classes to enter the fishery, and, in part, to possibly changed oceanographic conditions. Presumably the pilchards constituted a food organism for certain larger fishes. What has happened to the latter? To what have they turned as a substitute food? Presumably the pilchards consumed appreciable quantities of plankton food. What species have now found a greater abundance of available plankton and benefited thereby? Within recent years the dogfish (*Squalus suckleyi*) off the British Columbia coast have been extensively exploited, due to the demand for Vitamin A liver oil. These fish are considered a voracious predator of salmon, herring, flatfish, etc. What effect has their reduction in abundance had on these other species? These are merely examples of the changes going on in the ocean which with many others may be altering the picture of fish production very materially.

SALMON

The Pacific salmon fisheries have been for many years Canada's principal fishery. Five species are involved, the spring (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), sockeye (*O. nerka*), pink or humpback (*O. gorbuscha*) and chum (*O. keta*). While some study has been made (by tagging) of migration in from the ocean, through the fishing areas and on to the spawning grounds and some attention has been given to fishing intensity and suitable regulation of fishing to guarantee an adequate spawning escapement, chief consideration has been given to those fresh-water phases of the life-history which are within control and which may be altered to produce a greater production of young. To date the sockeye, the pink, the chum and the coho have been the subject of special study. By conducting long-term investigations in specific areas (Cultus Lake for sockeye, Foerster 1936, 1938a, 1938b, 1944, Foerster and Ricker, 1941; McClinton Creek for pink salmon, Pritchard 1936, 1944, 1948; and latterly Nile Creek, Vancouver Island, and Port John Creek for chum salmon under Mr. Ferris Neave's direction, Hunter, 1948) information has been obtained regarding the efficiency of natural propagation, i.e., production of fry or smolts migrating to sea, and the factors affecting spawning, incubation of eggs and survival of fry. Measures of increasing production are being studied and are being investigated as to their practicability. For pink and chum salmon which frequent the many coastal streams and lower tributaries of larger rivers whose stream flow is highly variable it is indicated that measures of stream improvement, control of water flow to guard against damage from freshet and drought may have very appreciable value. Certain measures of artificial propagation to achieve greater fertilization of eggs and greater survival of eggs and alevins are being investigated. For sockeye salmon, which spend at least one year in fresh water before migrating to sea, removal of obstructions to ascent to the spawning areas and improvement of spawning streams are of value. The influence of predator and competitor fishes in the lakes is also considered to be of significance and methods of reduction and control of the important species are being studied.

In all our salmon work it is recognized that we know far too little about the natural economy of our lakes and streams, the relationships existing between the various fish populations, the variations in abundance of plankton and the general effect of environmental conditions.

These have an intimate bearing upon the survival and development of young salmon and until we can evaluate their significance we cannot determine their limiting or influencing effect. For this reason the Fisheries Research Board of Canada proposes to undertake special studies of particular lakes and streams over a period of years to follow as closely as possible the changes occurring and their probable significance in salmon culture. With the information so obtained in hand, problems of predator control, competitor fish elimination, fertilization of lakes, etc., can be more readily appreciated and tackled.

Marine Fisheries

In many countries the problem in fisheries is that of developing suitable and efficient methods of exploiting the fish populations. The fish are present in abundance but fished for to only a limited extent. Along the Pacific coast of North America, however, fishing practices are highly developed and fishing intensity is at a peak. The requirements are, therefore, to limit the exploitation lest too many fish be caught and the maintenance of the fishery at an economic level be endangered. While there seems little danger that, through overfishing, serious biological depletion of the stocks can result, nevertheless depletion below the level at which fishing can economically be continued may occur. Therefore efforts are being directed to determining what constitutes safe catch and how fishing effort can be regulated to provide it and no more.

Herring

Along the British Columbia coast the herring (*Clupea pallasii*) fishery is an important one. This year the total catch is expected to amount to over one hundred thousand tons or approximately one thousand million fish. From tagging experiments it has been established that there are five reasonably discrete populations of herring along the coast with little intermingling between them. Hence for conservation purposes each must be considered separately and appropriate "management" policies devised.

At the present time two management procedures are being investigated. In one, operating along the lower east coast of Vancouver Island, a quota system of regulation is being carefully tested. Here, in 1936-37, an arbitrary quota limit of 25,000 tons was selected and maintained (Tester, 1945) until 1940-41, when it was raised to 30,000 tons. During the war years demand for high protein food became urgent and in view of the apparent abundance of herring in the lower east coast of Vancouver Island waters quota extensions of 20,000 tons were granted, thus allowing for the capture of 50,000 tons of herring in 1941-42, 1942-43 and 1943-44. In the first two years the increased quotas were reached or approximated but in 1943-44 the total catch fell considerably short. Observations on the spawning grounds suggested that at a 50,000 ton level the catches may have taken too large a portion of the total population. In 1945-46 the quota was again considered and raised from 30,000 tons to 40,000 tons for a proposed period of five years. The quotas have been readily taken. The whole purpose is to determine, by adoption of a quota system of regulation, the reaction of the herring stock to the fishing effort, as the effort or intensity is increased. At some level of exploitation the maximum sustained yield year after year may be achieved. During this whole period of investigation careful and extensive studies are made of the strengths of the age classes entering into the fishery, the amount of recruitment from new and younger year groups. Size records for each age group are obtained. During the fall herring fishing of 1948, the 40,000 ton quota was reached in less than one month of fishing operations with large quantities of herring still remaining in the areas for subsequent spawning.

The other experiment, conducted on the west coast of Vancouver Island, is designed along completely opposite lines. Here there is no quota and no restriction of the fishery except for a closing date when the fish are mature and repair to the shallow areas of the coastal inlets to spawn. The quality (oil content) of the fish is at that time poor. The desire is to see what effect a high intensity fishing may have on the stock of herring. It has been suggested that there is little correlation between the amount of spawning and the extent of recruitment of young fish to the stocks. Large spawnings do not always produce extensive recruitment; light spawnings frequently are highly productive of young fish. It may be that, if there is no satisfactory relationship between extent of spawning and production of young fish, any measures designed to produce large spawning escapements of herring may result in the loss of large quantities of fish that might otherwise be utilized commercially.

This experiment is now in its second year and it is apparent that for the one year when unrestricted fishing was allowed and a catch greatly in excess of those formerly taken resulted, no decline in the stocks occurred. There are indications that enough herring come into the spawning areas from the ocean after the fishing season has terminated to provide an adequate seeding. This experiment is being continued over a period of years. Close observations are being made on extent and degree of spawning and sampling of the catches to determine the year group composition and the contribution of each age class is undertaken. A study is also being made of the degree of survival of eggs and young each year, not only to reveal the factors limiting the survival—climatic conditions, oceanographic conditions, predators, etc. —but also to ascertain whether it be possible to obtain, from a measure of the young fish newly-hatched, a satisfactory indication of the extent of the population two years hence when these fish enter the fishery.

TRAWL FISHERY

During the Second Great War a demand for flatfish arose. The trawler fleet quickly expanded and fishing intensity increased quite appreciably, especially in Hecate strait areas. Little attention had previously been given to the flatfish fishery, the size of the stocks was unknown and immediately the question arose as to whether they could withstand heavy exploitation. Studies were therefore initiated as quickly as possible to assess the sizes of the populations before they had been appreciably reduced and their characteristics—sizes and ages of fish, etc.—changed and to lay a basis for evaluating the effect of the fishing drain upon them. This, as was expected, entailed not only extensive study of the catches landed to get size and age data and the changes occurring from year to year but also investigation of the migratory habits of the fish, spawning times and areas, rates of growth, etc. Four species of fish are chiefly involved, the brill, *Eopsetta jordani,* the rock sole, *Lepidopsetta bilineata,* the butter sole, *Isopsetta* *isolepis* (Hart, 1949), and, in more southern waters, the lemon sole, *Parophyrus vetulus.* The studies are continuing.

It was soon found, however, that the trawls take a large variety of other species of fish for either the fresh fish trade (grey cod, *Gadus macrocephalus,* lingcod, *Ophiodon elongatus,* rock fish, *Sebastodes flavidus, S. melanops, S. alutus, S. pinniger, S. brevispinis, S. maliger,* etc.) or for liver oil (lingcod, *Ophiodon elongatus,* dogfish, *Squalus suckleyi*). Statistics of the catches are collected and as opportunity presents, life-history studies are undertaken. (Barraclough, 1949.) One important feature is that some of these species, lingcod, greycod, dogfish, are taken also by other fisheries (long-line, hand-line, sunken gillnets). Competition between different types of gear thus occurs and presents a problem, sociological as well as biologically, which merits attention.

PILCHARD

For many years a very comprehensive study was made of the populations of pilchards (*Sardinops caerulea*) frequenting British Columbia waters. Tagging experiments conducted both in California and in British Columbia indicated that these pilchards were essentially of the great California stock taken at the northern extremity of their coastal migration. Only the larger individuals appeared to reach B.C. waters. Samples of fish taken from the commercial catches were used to obtain size and age frequency records. From these data the dependence of the supply upon certain year classes whose recruitment to the stock was heavy was realized. This was very apparent when a heavy influx of new fish appeared in 1940, presumably the result of a heavy spawning in 1939 in areas north of California. In Canadian waters young pilchards in their first year were very abundant, a most unusual phenomenon (Hart, 1943). This age group influenced the fishery for several years, in fact the population from 1943 to 1946 was largely dependent upon it, with no new age classes appearing to build up the stocks. As a result, and as predicted on the basis of the analyses of age-class composition, there has been no appreciable pilchard fishery in British Columbia waters in 1947 and 1948 and the outlook is still very grim. To what extent oceanographic conditions may have contributed to the decline by altering migratory paths remain unknown, but the notable decline in sardine abundance in California waters suggests that whatever factors are at work are definitely influencing and limiting recruitment of young fish to the coastal populations.

It may here be remarked that attempts to predict the supply of pilchards on the basis of year class composition and strength of young age groups undoubtedly were of value to the industry. Forecasts of poor supply prevented the fishing companies from outfitting vessels, manning canneries for full-scale operation, etc., and thereby reduced appreciably the losses which they had to take.

MINOR FISHERIES

While greatest attention is, of course, given to the commercially-important species of fish and the greater part of the research effort is directed to them, consideration is given, to a limited degree, to certain of the minor fisheries because of the part they play in supplying fish to a seasonal market. To some fishing companies and to some fishermen these minor fisheries are of importance. Among such are the eulachon (*Thaleichthys pacificus*), the anchovy (*Engraulis mordax*) and the soupfin shark (*Galeorhinus galeus*). At the present time efforts are chiefly directed toward completing our knowledge of life-histories, rates of growth, migrating habits, etc., which may have a bearing upon population studies and the effect of fishing drain. (Barraclough, 1949.) A bulletin (Hart and McHugh) giving in general terms our present day knowledge of the four species of smelts (Osmeridae) in British Columbia was prepared in 1944.

Crustacea

While studies were made several years ago (MacKay, 1942) of the Pacific Edible Crab (*Cancer magister*) and its fishery, little has subsequently been undertaken except for observations conducted on important crab fishing grounds on the north and east coasts of Graham Island, Queen Charlotte Islands, to obtain data on the fishing effort in relation to populations present, migratory habits and general distribution data. For shrimps, practically nothing has been done since certain life history and distribution data were collected by Berkeley (1929, 1930). Both these crustacean groups are becoming of increasing economic importance and it is felt that a survey of the coast to discover additional beds for commercial exploitation would be well worth while. Studies to determine the effect of fishing effort upon them would be advantageous in order to develop proper management policies.

In 1946 a shipment of Atlantic coast lobsters (*Homarus americanus*) was made to a Pacific coast lagoon to determine the likelihood of this species being introduced successfully into Pacific coast waters. Earlier attempts had been made in 1898, 1905 and 1916 on a small scale but the 1946 transplant involved some 2,000 individuals of "canner" size, ca. 6 inches in length. Unfortunately the planting suffered the same fate as the earlier tests because of the too high cost of erecting a barrier to the escape of the lobsters from the lagoon. Shortly after their introduction attempts to trap them were made. Little success was achieved and evidence obtained from recovery of tagged individuals indicated that the population had appreciably dwindled either from mortality or from emigration. Recapture of one lobster outside the lagoon suggests that migration from the lagoon may have occurred. Retention of some lobsters in a floating cage revealed that they thrived successfully in their new environment, moulting and mating normally and showing a good rate of growth. Possibilities of successful reproduction have yet to be investigated. Proposals for further experiments under better controlled conditions are being studied. At the same time a suggestion that Australian crayfish be introduced into British Columbia waters is being given consideration.

Shellfish

During recent years shellfish research has been confined to an attempt to rear Pacific oyster (*Ostrea gigas*) seed in tanks to (1) make unnecessary reliance on importation of seed from Japan (this was of great significance during the war) and (2) perhaps build up a more desirable local strain of oyster; and to a study (Quayle, 1939, Neave, 1941, 1947) of the butter clam (*Saxidomus giganteus*) fishery in order to develop a management policy that might result in a more stable yield year after year. Results of the oyster work have not been particularly promising thus far; conclusions regarding regulated clam digging are as yet indefinite. Further observations on the spawning of clams and the distribution of the larvae prior to setting are required. Likely occurrence of irregular spawnings, of rich and poor year classes make doubtful the value of quota limits. The presence of clam populations below low water line and beyond the digging areas suggests that these may represent sufficient spawning reserve to assure adequate reseeding of the beaches irrespective of digging intensity. The Provincial Fisheries Department has now taken over the shellfish resources and will conduct its own research.

OCEANOGRAPHY

The importance of knowing the relationship between oceanographic conditions and the abundance and distribution of fish is fully realized. It is felt that little can be done in attempting to understand the variations in abundance or availability of fish from year to year, whether due to varying survival rates or to differing distribution, without a long-term record of oceanographic conditions for correlation. At the present time information on coastal water conditions is being obtained from daily water temperature and salinity readings taken at eleven lighthouses along the coast. Three of these sampling stations were established in 1934, one in 1935, three in 1936, two in 1937, one in 1939 and one in 1941. In addition observations at the Pacific Biological Station at Departure Bay were commenced in 1914. These stations are being maintained and the samples regularly taken in order that there may be eventually available a long-term series of records which can be used to establish trends in the temperature and salinity conditions sufficiently for correlation with changes in fish abundance. These records are now being issued in a mimeographed form in a series of volumes entitled "Observations of Sea Water Temperature, Salinity and Density on the Pacific Coast of Canada". Six volumes have now been compiled bringing the data up to the end of 1945.

While considered to be of great value in future studies, particularly when useful forecasts of fish availability or abundance are attempted, it is desirable that these data be closely tied in or related to the conditions prevailing in off-shore areas. The latter may or may not have greater significance when dealing with certain species of fish, such as sardine or pilchard, tuna and salmon. Plans are being developed to initiate an off-shore oceanographic programme this summer which, it is hoped, will be the beginning of a long-term operation to provide the salient physico-chemical data for future study of fish movements and survival. In due course it is anticipated that certain biological phases will also be collected, particularly plankton, in order to define more clearly the basic relationships of the various factors involved.

CONCLUSION

It may be said, therefore, that fisheries research on the Pacific coast is directed to obtaining those basic facts concerning each important fishery which will

(1) Make possible the development of correct management policies striving for optimum catch on a sustained yield basis.
(2) Reveal the factors limiting survival of young to the end that their correction or control may increase production materially.

(3) Result in a clearer understanding of the relationship of environmental factors to distribution and abundance of fish and permit early reliable forecasts to be made for the benefit of industry.

Progress cannot be too rapid. There are no reliable short-cuts to achieving a clear understanding. Variations in results from year to year must be anticipated and allowed for in making final analysis. The end result, however, a fuller knowledge of the factors involved and their significance will lead to a more adequately managed fishery, a more safely-protected natural resource whose exploitation can be more economically and profitably undertaken and whose future can be assured.

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THE EXPERIMENTAL AND PHYSIOLOGICAL APPROACH IN FISHERIES BIOLOGY

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The science of fisheries biology has developed slowly. There are those who would insist that this field of applied biology is not, as yet, sufficiently well developed to constitute a distinct field of science. It is certainly true that until fisheries become something more than the natural history of fishes; the anatomy, embryology and physiology of fishes; the statistics of fishery yield and fish culture it could not be recognized as a distinct discipline. These subjects all form a part of the science of fisheries but this science is something more in that it is an applied field of Biology with its own techniques and particular aims. It includes a body of organized knowledge regarding the supply of commercially important fish, the variations in supply and their causes, and the methods of harvesting and marketing the resources. It has as its ultimate aim the establishment of maximum continuous yields of important food fishes, captured in an efficient and economical fashion and marketed in a wholesome and nutritious form. This is admittedly an infant science but other branches of applied biology—for example, Agriculture and Medicine—were recognized and taught before knowledge was as advanced in those fields as it now is in fisheries.

In the past, work in fisheries biology has been largely a matter of exploration. Until the extent and nature of the resources of the sea are known, until the kinds of fish, their life histories, foods, spawning habits and migrations are elucidated and until the movements of the ocean waters and the effects on these of winds, currents and river discharge are established, a scientific management of fisheries resources is impossible. There are still many blanks in our knowledge but sufficient facts are now available to provide a basis for management programmes. We are able to estimate the abundance of some of our important food fishes, determine their ages, rates of growth and mortality; to follow their migrations, foresee the effects of various biological and environmental factors on the population and, finally, to predict with some degree of precision the yield to the fisherman. When it is possible to determine the maximum continuous yield under definite conditions and thus reduce the element of gambling in fishing operations, then prediction is possible and it is reasonable to say that we have a science of fisheries management. As yet this ultimate goal has not been entirely achieved for any fishery but in the last 20 years the rather nebulous aims of the early fishery biologists have disappeared and the science has passed from the descriptive stage to the quantitative stage of a maturing science.

Three lines of thought have developed in an attempt to apply the accumulated systematic knowledge to a scientific management of particular fishery resources. The earliest attempts were based on the idea that reproduction was primarily at fault. Fish hatching and planting was looked upon as a panacea for the assumed or real scarcities of fish. This was the prevailing idea for 50 years. But the effects of these fish planting programmes were not manifest. The cost mounted and it was impossible to demonstrate the benefits. Then followed the intensive fishery investigations of the first half of the twentieth century which were crystallized in a "theory of overfishing"—a thesis that there is a most profitable time to harvest a crop of fish; that a knowledge of growth and mortality rates of a population will enable us to predict the maximum continuous yield and thus establish rational programmes for exploitation. This thesis has been clearly formulated in the writings of Baranov (1918), Russell (1931), Graham (1935) and Thompson and Bell (1934). More recently, Ricker's numerous articles have provided a summary of methods for the quantitative approach to the population problem (Ricker, 1948). But the actual populations of fish have often reacted in a very different way from the theoretical populations and recently a third line of thought has become apparent. Fishery biologists are now particularly conscious of the importance of cyclical variations and the effects of the environment on the abundance of fish (Huntsman, 1948; Burkenroad, 1948). It is suggested that man's fishing activities have had little or no effect in comparison with the effects of adverse temperature, salinity or other factors at certain critical times. It is becoming a commonplace to hear the remark that we require experimental work to test these various ideas or to study the effects of these different factors on fish.

These changes in thought emphasize the fact that fisheries science is young and developing. Future scientists should be able to evaluate the importance of the different approaches which have been made. Without doubt, there has been a seemingly sound basis for each line of thought developed. Although today it is evident that reproduction of the population has not been at fault in certain cases and that time and money have been wasted on hatching and planting fish (Foerster, 1929), nevertheless, it is equally true that fish hatching and planting has its place in restocking policies and it seems probable that the present fish cultural methods can be greatly improved. Again, no amount of computation and calculation can forestall the collapse of the American west-coast pilchard fishery if it is dependent on phenomenal brood years which do not appear because of unfavourable salinity conditions. However, the industry is benefited by the predictions which the fishery biologist can now make regarding the pilchard fishing even though these predictions are not particularly favourable. If the quantitative studies of the past have not been as successful as anticipated it is because of a lack of certain basic information—primarily knowledge regarding effects of environmental factors on animals and animal populations. Observation and exploration are fundamental but experimental analysis is necessary to carry the science beyond the stage of trial and error.

The experimental approach in fisheries biology, as in every field of science, has many different aspects. Two avenues would appear to be important and productive. The first of these will include all of those experiments which involve a manipulation of the stocks of fish as they occur in nature. The second will include the detailed analysis of the basic physiology and behaviour of fish under controlled laboratory conditions. Individual investigators have been active in both fields for many years but, in the past, the experimental approach has not been emphasized in the major fisheries programmes. At the present time there appears to be a definite move toward experimental and physiological studies in fisheries research programmes.

Several of the early workers in fisheries saw the necessity for experimenting on the stocks of the commercially important fish. Tagging work introduced by Peterson (1896) can scarcely be considered in this category since this procedure is only a means of more accurately observing the distribution and movements of the population. However, even before this (1886) Scottish research workers attempted to discover the effect of trawling in the Firth of Forth and St. Andrew's Bay by closing the areas to the trawlers and carrying on experimental trawling for a period of ten years. The results of this investigation were not particularly significant (Graham, 1948) but the approach through experimental fishing is a most important one in fisheries investigations. In this field the British workers have made outstanding studies on the effects of different mesh of nets on the size of the fish captured and on the types of gear which will permit the escape of the undersized fish (Davis, 1934). In Canada, the Fisheries Research Board has seen the importance of the large scale experiment on stocks of fish. Foerster (1929, 1944) compared the effects of artificial and natural spawning of the stock of sockeye salmon in Cultus Lake, B.C. and Foerster and Ricker (1941) observed the effect on these populations of young salmon of removing predator fish. Recently, Tester and Stevenson (1947) have attempted to determine the effects of unrestricted fishing on the large stocks of herring on the west coast of Vancouver Island. Indications are that restrictions placed on the herring fishermen of this area in the past may have been quite unjustified. Knowledge of this type is most urgently needed. Fisheries legislation has too frequently been based on a fear of the effects of overfishing rather than any scientific demonstration that overfishing has occurred. It is only by subjecting the stocks to various fishing intensities and following the effects scientifically for a number of years that information can be obtained for sane legislation.

Many of the results obtained in this first type of experiment will remain in the field of empirical observation until the basic physiology of fish is better understood. This is particularly true insofar as we are concerned with the effects of environmental factors on the size and behaviour of the population. A population of fish has a definite reproductive capacity and a fundamental pattern of behaviour. Both of these characteristics are of prime importance to the fisherman and both are decidedly modified by environmental factors. An understanding of the effects of environmental factors on these capacities is necessary if the stocks of fish are to be managed scientifically.

At least three different approaches to the physiology of fish in relation to the environmental factors operating on them were emphasized at the recent meetings of the Canadian Committee on Freshwater Fisheries Research held in Ottawa, January, 1949. The behaviour of the animal in relation to various stimuli may be described quantitatively in terms of the direction of activity, the distance moved, and the frequency of the particular movement. Such a description of behaviour is being attempted by K. C. Fisher and his group in the University of Toronto. This is a precise quantitative analysis of the responses of an organism to a stimulus. On the other hand, the emphasis may be placed on the environmental factors as they affect activity. Thus Fry (1947) in an analysis of the effects of temperature on fish would describe this as a *lethal factor* in that it destroys the integration of an organism; a *masking factor,* in that it prevents some other factor from operating on the organism; a *directive factor,* in that it directs the activity of the animal in a gradient; a *limiting factor,* in that it governs metabolic rate by virtue of operating in the metabolic chain or a *controlling factor* in that it governs the rate of metabolism. The emphasis here is in the description of behaviour according to the manner in which the various environmental factors influence the organism. Both of these approaches are important to an understanding of the behaviour of fish. Huntsman (1948) has emphasized the necessity for studying the response of the organism as a whole to what it faces where it lives (Biapocrises), but a complete understanding must rest on a detailed analysis of separate factors.

Finally, it was emphasized that an animal lives in an internal environment as well as an external one. The pattern of behaviour of the fish in its external environment is dependent upon the internal biochemical constitution. For example, the lethal temperature relations of fish can be changed by modifying the body fats with suitable diets (Hoar and Dorchester, 1949); responses of fish to currents can be altered by the use of thyroid hormone (Fontaine, 1948) and conditioned responses to light can be changed with gonad hormones (Vanderplank, 1938). A knowledge of the internal biochemical background is necessary to an understanding of the changing patterns of activity of a fish. The salmon migrates down stream to the ocean and may move long distances in the ocean before migrating in the opposite direction to spawning grounds. This changing pattern of reactions to various stimuli is evidently related to changes in glandular activity and biochemical constitution of the animal. The animal is endowed with certain patterns of behaviour which can be released by very simple stimuli (Tinbergen, 1948) and modified by changes in the nature of the internal environment (Fontaine, 1948). Very little work has been done in this productive field of investigation.

These physiological investigations will give a clearer understanding of the distribution of fish, their cycles of abundance and their behaviour. This is essential for accurate predictions of yield and efficient exploitation of the stocks.

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Discussion

Professor Yonge raised the question of over-fishing and pointed out the need to distinguish between pelagic and demersal fishing. Dr. Hubbs agreed, adding that any shore and certain fresh-water fish can be depleted by over-fishing. He pointed out that the paper did not mention environmental control, such as experiments in fertilization of lochs in Scotland, and that environmental control should be co-ordinated with analyses of stocks and population. Professor Yonge pointed out that an environment such as the open sea could not be modified.

THE TRAWL FISHERY ON THE PACIFIC COAST OF CANADA

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The first trawling of which there is record in the Province of British Columbia, Canada, was done by J. C. B. Shannon and Rory Martin of Vancouver about 1911 using a forty-foot boat powered with a 16-18 h.p. gasoline engine. Working on an unexploited fish population there was no necessity to travel far to reach productive fishing grounds, and most of the landings came from English Bay at the harbour mouth and Sand Heads at the mouth of the Fraser River. The fishery was primarily for lemon sole which were for the most part sold whole rather than filleted. A few years later others entered the fishery and by 1919 the fishing effort was extended across the Strait of Georgia to Trincomali Channel, Porlier Pass, and Dodd Narrows (Boat Harbour). In 1920 fishing grounds were extended beyond the Fraser River lightship toward Point Roberts. During this period lemon soles were the principal species sought, but all other common species of food fishes were marketed with the exception of the grey cod.

A trawl fishery with steam trawlers was carried out in Hecate Strait for a few years following World War I.

Prior to 1936 vessels from the State of Washington ports had developed fishing grounds in the open Pacific off the Olympic Peninsula. Later, about 1936, Canadian vessels started working these grounds and more especially joined the United States vessels in fishing the grounds along the west coast of Vancouver Island. This fishery was carried out principally for brill by the United States vessels, but Canadian fishermen landed a considerable proportion of lemon soles as well. By 1940 trawling was undergoing a marked increase due to the expanding war-time demand for food fish and to the increasing realization of the profits to be made from the sale of dogfish liver as a source of Vitamin A-producing oil. Trawl gear is versatile in the fish it captures and during that period almost any kind of fish could be sold. Attracted by good financial prospects more trawlers entered the fishery and an increased proportion of trawl fishermen used this type of gear for the whole fishing year. More recently, increasing popularity of frozen flatfish fillets has helped to keep trawling a lucrative British Columbia fishery.

The continued demand for flatfish has not yet led to a stable fishery. Increasing knowledge of the fishing grounds by fishermen has led to increasing relative fishing intensity for preferred species which give good yields on filleting as well as having good flavour. Notably the concentrated fishery for lemon soles gave way in 1947 to one for rock soles, and that species in turn was displaced in greatest demand by the brill during 1948. In the last two or three years the less saleable species of fish have not been landed consistently with the result that on some occasions large quantities of grey cod and rockfishes taken incidentally have been discarded.

As part of the programme of investigating this fishery a sample as large as possible of the trawl fleet is met at the port of landing and estimates are recorded of the proportions of the various species landed. The break-down by species of the sample of the catch dealt with is given in Table 1. It appears that in 1946 there was a definite bias in favour of butter sole landings being recorded but for the most part the samples are reasonably representative. In examining the table it should be kept in mind that dogfish landings are recorded in pounds of liver—about a seventh of the weight of the whole fish.

TABLE 1.—PERCENTAGE OF THE MORE COMMON SPECIES IN THE COMMERCIAL LANDINGS BY TRAWLERS

Common Name	Scientific Name	1946	1947	1948
			Oct. 1946-Oct. 1947	Nov. 1947-Oct. 1948
Lemon sole	*Parophrys vetulus*	14·1	10·4	12·6
Rock sole	*Lepidopsetta bilineata*	9·6	29·0	11·3
Brill	*Eopsetta jordani*	8·4	15·5	38·9
Starry flounder	*Platichthys stellatus*	4·2	2·6	1·0
Butter sole	*Isopsetta isolepis*	18·6	2·7	3·6
Rex sole	*Glyptocephalus zachirus*	1·0	0·4	0·8
Dover sole	*Microstomus pacificus*	2·9	6·6	0·8
Sand sole	*Psettichthys melanostictus*	—	0·1	0·1
Long-jaw flounder	*Atheresthes stomias*	—	—	+
Unclassified flatfish		10·0	5·4	7·6
Grey cod	*Gadus macrocephalus*	13·7	12·2	6·0
Lingcod	*Ophiodon elongatus*	9·7	4·8	7·1
Rockfishes	*Sebastodes* spp.	3·7	1·3	0·5
Skate	*Raja binoculata*	0·3	0·6	0·3
Perch	*Damalichthys vacca*	0·1	0·1	+
Dogfish liver	*Squalus suckleyi*	2·9	4·9	4·7
Black cod	*Anoplopoma fimbria*	0·1	+	0·2
Hake	*Merluccius productus*	0·1	—	+
Whiting	*Theragra chalcogramma*	0·1	+	—
Ratfish liver	*Hydrolagus colliei*	0·4	+	+
Herring	*Clupea pallasii*	—	—	4·1
Octopus	*Polypus hongkongensis*	0·1	+	+
Crab	*Cancer magister*	—	0·1	+
Other species, "mink feed" which includes a substantial amount of young flatfish, etc.		—	3·1	0·4

The analyses of the landings shown in Table 1 give an inadequate impression of the interference with the natural economy of the coastwise waters. Of the food fishes great numbers of rockfishes and grey cod are caught in addition to those landed, the excess being discarded at sea. Marginal species which are frequently caught in numbers but are usually discarded are the whiting, hake, and long-jaw flounder. Many small flatfishes of various species and several kinds of roundfish are caught and thrown overboard. Some of these are killed by being so handled, all are disturbed. The extent to which the fishery disturbs the economy of the sea and affects its productivity cannot be reasonably estimated nor can an accurate appraisal be attempted of the way in which trawling affects the bottom as an habitat for food fishes. It is possible, however, to determine with more or less accuracy the predator and competitor relations existing among the fishes commonly taken in trawl gear, in the expectation that the results of the fishing may be anticipated or at least explained.

Because the trawl fishery off the British Columbia coast is not yet stabilized in regard to grounds or products, and because there is evidently interaction between the different species it exploits, the scientific investigation of the fishery as carried out by the Fisheries Research Board of Canada has been planned on very broad lines. Sampling for length, sex, and age has not been limited to the most important commercial species, although naturally they have received the most attention. Early tagging work was spread over many types of fish although recently the tendency has been to narrow effort to the important commercial kinds known to react well to tagging and to concentrate on the more important runs in the expectation of obtaining results which lent themselves to objective analysis. An additional major feature of the programme is the study of the food of all the fish taken in the gear. Samples of the fish taken during the routine operations of the "Investigator No. 1" or chartered vessels are examined for stomach contents whenever opportunity presents itself. In recognition of the observation that in many species the sample rather than the individual is the unit of variation in diet preference the results are tabulated and filed according to sample so as to provide an authoritative record of food relationships among the bottom fishes. It is the hope that the general programme may provide an understanding of the factors affecting the supply of demersal fish and the relationships between them and other forms while the more specialized studies elucidate the vital statistics of the most important fish species.

Discussion

Professor Yonge stressed the probable damage done by the trawl on sea bottoms. Dr. Foerster stated that indications are that the damage done is small, and that in British Columbia the same ground is not often covered. Dr. Hubbs said that some areas in the Gulf of California with soft mud bottoms had been considerably modified by trawls, particularly where trawling was frequent in one area. The surface layer of the bottom is destroyed and the fish feeding on this layer depleted. Dr. Hubbs drew an analogy between the harrow and the trawl, saying a certain amount of trawling probably would not be harmful. Dr. Cottam stated that at George's Banks attempts were being made to photograph the bottom and this could be used to determine damage by trawls. Mr. Cassie stated that it had been found by experiment in New Zealand that definite alterations, due to seining operations, had occurred in the Hauraki Gulf, e.g. seaweeds had been swept away and less weed was now being brought up in the seine than previously. Quantitative determinations had not been made.

TECHNOLOGICAL ASPECTS OF FISHERIES RESEARCH BY THE FISHERIES RESEARCH BOARD OF CANADA

By Neal M. Carter, Pacific Fisheries Experimental Station, Vancouver

[*Abstract*]

Technological investigations by the Fisheries Research Board of Canada are undertaken at three of its six stations, two on the Atlantic coast, and one on the Pacific coast of Canada. Each station tends to specialize on certain aspects of fisheries technological problems peculiar to its coast, but considerable work of common interest to the fish processing industries of the whole of Canada is undertaken with a minimum of duplication of effort. Since the establishment of the Experimental Stations at Halifax, Nova Scotia, in 1925, at Prince Rupert, British Columbia, in 1926, and at Grande Riviere, Quebec, in 1936. the fisheries technological fields investigated have been most varied.

Some of the outstanding achievements have been: the development of an early prototype of the present plate-freezer system of quick-freezing of fish fillets; the initial drawing of attention to the Vitamin A and D contents of Canadian fish and fish liver oils; the introduction of new scientific principles in the drying, salting and smoking of cured fish; the demonstration of improved methods for the refrigeration of railway cars for transcontinental shipment of frozen fish products; developments in objective methods for determining the degree of incipient spoilage in fish products and a new concept of the nature of bacterial spoilage in fish; the introduction of chemical deterrents to the spoilage of fish products by bacterial action and oxidative rancidity; sanitation in fish processing plants; the collecting and publication of authoritative data on the chemistry and technology of marine animal oils; the improvement of the quality of marine animal oils; the utilization of waste fish products for human consumption, industrial or pharmaceutical products, etc.

The paper deals with a summary of the highlights of such investigations, with particular reference to current work.

Discussion

To a request by Professor Richardson for general figures on the economic value accruing from the improved utilization of by-products in the industry, Dr. Carter answered that in December, 1948, if the by-products were fully utilized, there would have been an 8 per cent. addition to fish products as landed. Asked by Dr. Hubbs to elaborate on the development of insulin extracts from whale pancreas, Dr. Carter said that a new company in British Columbia had permitted a research worker, who also acts as official observer, to be present on the station. Section samples had been examined by Dr. Fisher, whose report showed a high potency for whale pancreas. Mr. Dawbin asked if figures for oil and vitamin content of the liver of the humpback whale were available. Dr. Carter replied that the yield of liver oil was lower in the humpback than in the sperm or Sei whales; vitamin content and oil quantity varied from portion to portion of the liver and from whale to whale.

THE SCHOOL OF FISHERIES, UNIVERSITY OF WASHINGTON

By R. Van Cleve, University of Washington, Seattle

By the turn of the century the State of Washington had become a major fishing centre. Its fishermen were not only harvesting the salmon runs which spawned in the rivers of Oregon, Washington, and British Columbia, but also were working in the deep waters off shore and in the fisheries in Alaska. A large industry had been built around these fisheries, with its headquarters on the Columbia River and on Puget Sound. At the time of the First World War, the fisheries of the Northeast Pacific had not yet reached their peak of development. The harvest of sockeye from the Fraser River runs reached a new high level in 1913, and the other large fisheries in Washington, British Columbia, and Alaska were still expanding. Conservation was a term that at that time had no place in the vocabulary of the fishing industry.

The abundance of fish and the easy profits to be made from their exploitation furnished incentive sufficient to bring about the full development of the fisheries. As the need arose, more efficient gear was invented to make fishing easier under more difficult conditions, and as the fish became harder to catch on the banks near home, more efficient vessels were built which extended the range of operations. The rapid growth of the country made it profitable to continue the exploitation of these natural resources even after the cream had been skimmed by the early adventurers. As long as new grounds remained to be fished the principal concern of everyone was the development of better methods of fishing and the expansion of operations.

In 1913 Mr. Hugh M. Smith, at that time the U.S. Commissioner of Fisheries, suggested that a school should be established "to train fisherfolk" in more efficient methods of fishing, as well as of handling and processing the catch. His plan probably resulted primarily from a trip he had made through Japan. That nation had grown to be the largest producer of fish in the world. Since fish was the principal source of protein in the Japanese diet, and a major item of foreign exchange, the industry was heavily subsidized by the Government. A large school had been established to teach men how to fish and how to handle and process the catch. Apparently Mr. Smith felt that this school contributed materially to the pre-eminence of Japan as a fishing nation.

In the United States, agriculture had been similarly subsidized through the founding of agricultural colleges in almost every state. These colleges had been successful in developing more efficient farming methods and producing bigger crops. It was logical to assume that similar benefits would accrue to the fisheries industry from a fisheries college. This suggestion of a fisheries school was received enthusiastically in the growing north-west area, but World War I delayed its establishment. At the end of the war, the project was again taken up, this time by Mr. John N. Cobb, who had been an employee of the U.S. Bureau of Fisheries and later was editor of the north-west trade magazine "Pacific Fisherman". Mr. Cobb was interested in the Japanese fisheries school, and believed that an institution patterned upon that in Japan would help to develop our fisheries, and would be a factor in putting them on an equal footing with the Japanese. Such a school was founded at the University of Washington in 1919, with Mr. Cobb as Director. The original faculty included Dr. Embody, later of Cornell University, New York; Dr. Carl Fellers, now of Massachussetts State College; and Professor Trevor Kincaid. Soon after the school was started, a curriculum was set up which placed most emphasis on training in the techniques of fishing, and in the canning, salting, and processing of fish. Conservation was confined to training in systematic ichthyology, and hatchery practices. The faculty was soon built around young men who were most interested in the techniques of net building and cannery operation.

During the late 1920's, the condition of the fisheries in the North-east Pacific had changed. After a rapid expansion over the greater part of the range of the halibut in this area, unmistakable signs of growing scarcity of that species had become apparent. The International Fisheries Commission had been formed to investigate the condition of the halibut fisheries, and to determine what steps might be taken to prevent further decline, and if possible to build up the supply of fish. Other major fisheries in the area had also begun to show that the supplies of fish were not inexhaustible, and conservation was beginning to be recognized as necessary to the continued well-being of the fishing industry. With this change in the industry, a change in the objectives of the school was inevitable.

Dean Cobb died in 1929, and in 1930 Dr. W. F. Thompson, at that time serving as Director of the International Fisheries Commission, was made Acting Director of the School of Fisheries. Dr. Thompson had studied fisheries biology under Doctors David Starr Jordan and C. H. Gilbert at Stanford University. His primary interest was in biology and, under his leadership, all training in fishing and canning techniques was dropped, and a new curriculum was adopted in the field of fisheries biology and conservation.

Since the North-west had become a centre of a large fishing industry, when the field of fisheries conservation developed, it was natural that it should become a centre for the various agencies concerned with fisheries biology and conservation. This circumstance was particularly favourable for the School of Fisheries, since it made it possible to supplement the formal training offered in the classroom with practical experience in fisheries research. By 1940 five different state, federal, and international agencies had set up research staffs in Seattle, either on or near the University of Washington campus. These were the U.S. Fish and Wildlife Service, the Washington State Department of Fisheries, the Washington State Department of Game, the International Fisheries Commission, and The International Pacific Salmon Fisheries Commission. The successful work of the International Fisheries Commission in building up the halibut fisheries had by that time awakened the industry as well as the conservation agencies to the value of sound biological research.

By 1947 the industry had contracted with the University of Washington to make an investigation of the salmon fisheries in Alaska, and the Fisheries Research Institute had been founded. The Applied Fisheries Laboratory had also been added to the active research agencies operating on the University campus. In the State of Oregon, an active programme of fisheries research had been undertaken by the State Fish Commission with a staff composed almost entirely of graduates of the University of Washington. Other graduates of the School of Fisheries had become associated with various fisheries departments throughout the United States and in foreign countries.

When fisheries conservation work was resumed on a large scale at the end of the Second World War, the demand for fisheries biologists far outstripped the supply, and, with rising wages and increased opportunities available, the school was taxed far beyond its capacity for the training of men. It was at this time that Dr. Thompson was succeeded as Director by Dr. W. M. Chapman. The latter, after spending a year in re-organizing the school, took a leave of absence to act as Special Assistant in Fisheries to the Under Secretary of State, and the writer became Acting Director of the school in 1948.

Objectives of the School

The history of the School of Fisheries at the University of Washington has shown that the objectives of the school have reflected the conditions of the industry. During the period of expansion, when depletion was considered by many to be a matter of only theoretical importance, it was natural that the school should develop along purely technical lines. However, when the need for conservation became plain, and the value of biological research had been proven, a change in the curriculum was demanded. The changes in leadership during the past few years have therefore had no affect upon the essential objectives of the school. Greatest emphasis has remained on fisheries biology and conservation. The training programme has been strengthened during that time by additions to the staff which now make it possible to offer a sound course of training in fisheries biology, as well as supervision in a wide field of research.

The task of training fisheries biologists for research is defined by the problems that are faced by conservation agencies. Most fisheries in the North-eastern Pacific have passed through the primitive phase of expansion. In some of the great ocean fisheries full development has been followed by increasing instability as the abundance of fish has fallen due to overfishing. The condition of the stocks of anadromous fish along the west coast of the United States has suffered further through the construction of dams and other obstructions in their spawning streams. The fisheries biologist must solve the problems of defining and measuring cause and effect in the relation of industry to fish populations. He must also find some way to provide passageway for anadromous fishes up and down stream past the dams that block their migratory routes, or he must devise some method of replacing the lost spawning and rearing areas. Another alternative is the loss of our west coast salmon, which seems an unnecessarily high price to pay for industrial development.

Marine Fisheries Biology

The essential objectives of marine investigation are definition of the limits of distribution of populations and sub-populations, and measurement of abundance within each independent unit. The relation of the separate stocks of a particular species to the fishery, and the bases for determining the productivity of any species are sought through measurement of rates of population growth, recruitment, and the natural and fishing mortalities. On this foundation, regulations may be formulated to build, or to establish a fishery at a high level of continuous yield. Special methods of study for use in marine fisheries biology have had to be devised because of the relative inaccessibility of marine fishes. Complex statistical problems are encountered in sampling populations of organisms that can be observed only indirectly; and interpretation of results is further complicated by the differences in life histories of the various species.

Involved in such work are the principles of fish population dynamics worked out originally in theoretical form by Baranov, and further elaborated by Thompson and Bell, Ricker, Graham, Russell, and others. The relationships between natural fluctuations and the effects of exploitation have not yet been defined in fisheries, and this deficiency has caused some doubt of the effectiveness of conservation regulations. This question, based in part upon false premises and incomplete analysis of data that may be incomplete, is one that nevertheless demands consideration and study. Work is needed on the population changes that actually occur in natural stocks under varying natural and artificial conditions, in order to evaluate the relative importance of natural and artificial factors in different species of fish.

Freshwater Fisheries Biology

Freshwater fisheries present different problems and possibilities in fisheries work. Accessibility to fishing in heavily populated areas precludes the possibility of maintaining natural stocks of wild sport fish such as trout, without resorting to artificial propagation. In fact, the sport fishing pressure is so great in some areas that game can be provided only by planting artificially reared fish of catchable size, and the entire plant may be caught within a few days of releasing the fish in the stream. Problems in hatchery operation, planting programmes, nutrition, and feeding are basic ones that may involve savings of thousands of dollars. Principles of population dynamics are again encountered in freshwater studies, with conditions possibly more simply defined than at sea.

The development of streams and lakes for power, irrigation, flood control, navigation, etc., has raised a number of problems which unfortunately were not foreseen and studied before solutions were demanded to save the fish. The anadromous fishes have suffered most from the dams, and of these fish the West Coast salmon has been the most important. Impoundment of water by dams changes completely the conditions in a stream. Spawning beds, formerly covered by a few inches or feet of well-aerated water, are submerged beneath many hundred feet of stagnant water. Silt is deposited, and the flooded area is lost forever. Further hazards are met by young fish on their downstream migration, in the form of unscreened irrigation canals or power turbines. Those passing over spillways may be killed by the powerful turbulence at the base of spillways—if they are improperly designed from the standpoint of the safety of fish. Ascent of adult salmon over dams has been provided for by means of fish ladders. Though these structures have been built in various ways for many years, they have been operated on the theory that if one or a few fish used them, they were completely successful. No one has, as yet, measured the percentage of mortality that must inevitably be suffered by fish which are delayed for varying lengths of time in their attempts to surmount dams—even those with "successful" ladders. When power turbine capacity plus volume of irrigation water surpass the volume of flow of a river, long stretches of stream beds may be dried up during periods of low flow, and another fatal barrier to the upstream migration of adult salmon is created.

Technology

The curriculum of the School of Fisheries, having swung from almost pure technology and fishing techniques to pure biology, was plainly not in equilibrium with the needs of the industry. While the prices of the raw product and of labour were low, fresh fish and manufactured fish products could compete on the open market with other foods by the simple expedient of selling at lower prices. Good profits could be made under these conditions, so that there was little inducement to make revolutionary improvements in the handling or processing of fish, especially since such improvements would have cost large sums of money. It was easier still to sell fish at high prices during the late war, and the increased costs of the raw products caused little concern, and profits rose still higher. The inevitable readjustment is now taking place, and with general inflation still holding, the fishing industry finds that its past neglect of the search for better methods of handling fresh fish, of canning, and the development of new and more desirable products, has caught up with it. It is not only encountering competition from other foods at home, but must obviously look forward to meeting lower-priced products from other fishing nations. The need for making up for this neglect has been recognized, and a demand for well trained fisheries technologists has arisen. This need was seen several years ago at the University of Washington, and plans were laid for again including fisheries technology in the curriculum of the Fisheries School. A lecture course in this subject was begun in the Fall of 1945, and in the Fall of 1948 a laboratory and lecture course with a full-time professor of fisheries technology was instituted. This programme attracted the interest of a number of graduate as well as undergraduate students. Additional formal training is planned, and with the expansion of graduate and faculty research, this field is expected to develop rapidly to a place of leadership, where material aid may be afforded in the solution of many of the problems now facing the industry.

A partial solution of the problem of increasing the raw-material supply for growing markets by a further expansion of the tuna, spider crab, and trawl and other fisheries, still appears to be possible. This will involve major advances in fishing and fish-handling processes, some of which have been worked out in other fisheries and now must be adapted and improved to fit the specific needs of Pacific Ocean fisheries. This cannot be considered a substitute for the conservation of the fisheries already over-exploited.

School of Fisheries Curriculum

Training in the School of Fisheries is designed to enable students to develop their chosen field in fisheries biology research or in technology, and is not intended to drill them in particular methods. Techniques in these fields are developing so rapidly that it would be useless to base a programme primarily on the study of current methods. Basic principles of importance in developing new lines of research and new methods must be stressed in such a field.

Most students enter the Fisheries School after two years of university preparation in the basic sciences of zoology, chemistry, and mathematics, with bacteriology and additional chemistry substituted for some zoology in the preliminary training of technologists. A course of fisheries lectures by leading workers in the various research organizations is also given during this preparatory phase to aid students in orienting themselves in fisheries work. Background work is continued in associated sciences throughout the fisheries training.

The fisheries training follows in a logical sequence, beginning in the student's third year of university work with a year's training in comparative anatomy, physiology, and classification and identification of fishes. In addition, a year's course is offered in the classification, life histories, distribution, and methods of cultivation or capture of commercial aquatic invertebrates. These two courses furnish the basic foundation upon which all subsequent work is built. More advanced students are offered a year's course in the general biology of fishes, including the study of the migration and inter-relationships of fish populations; the reproduction, larval and postlarval life of marine fishes; and the relation of hydrographic conditions, food, etc., to the distribution, abundance and availability of various species of fish. This is followed by a year's course in the more mathematical phases of fisheries biology, including the study of population growth and enumeration, the study of population dynamics, and the influence of natural and artificial factors on variations in yield.

In the field of freshwater fisheries biology, a year's course is given which covers methods of hatching, rearing, collection, and incubation of salmonoids, and related problems; the nutrition of fishes; and finally the problems of management of freshwater fisheries. This is supplemented by a course in the communicable diseases of fish.

As noted above, courses in fish technology have been added to the curriculum this year to meet the needs of the industry. At present a year's course is offered which covers the application of chemistry, biology, and engineering to the canning, curing, and freezing of fish and shellfish; and to the preparation of fish by-products, oils, meals, etc. Another course has been developed through a series of lectures by authorities in the various fields of the fishing industry. As equipment and facilities become available, additional technological training of a more advanced character will be offered.

RESEARCH

The research programme of the school is probably unique in that most of the problems form part of the programmes of the various fisheries conservation agencies in the North-west. Most of the theses written by the students are the results of practical investigations carried out by professional biologists and brought back to the school by them. This merger of the work of the school with that of the conservation and research agencies has been fortunate indeed, since it has made available to students the use of research equipment and facilities that the school lacked. In addition, the practical aspects of such work and their influence on the thinking of the school, has kept the scholastic objectives clear.

Ample room and equipment for graduate study and research will be provided, for the first time in the history of the school, in the new quarters which are now under construction. The new building will be equipped with adequate storage space for fish collections, and will provide room for working on them. A small freshwater hatchery with outdoor rearing ponds will be constructed for continuation of the valuable work in breeding and nutrition that has already saved hatchery operators thousands of dollars through cheaper and more efficient diets. Constant-temperature facilities are planned, with circulating fresh water; and salt water aquariums are to be constructed with a closed circulating system. Other facilities, such as an isolation room for study of fish diseases, one for microscopic technique, projection rooms, etc., are all to be included. Of great interest to research will be the library in which all fisheries literature from the University library system will be concentrated.

Marine fisheries research, aside from that which forms part of the programmes of other organizations, will be built around the study of the fishes of Puget Sound. This work will be carried out with a 50-foot diesel boat of purse seine design, which is already in operation. When fully equipped, this boat will provide collecting and sampling facilities which will make the entire Puget Sound area available as a laboratory. Unlimited possibilities are thus presented for the study of the life history, distribution, and relationships between populations of Puget Sound fishes and their natural environment.

The latest machinery is being obtained for experimental work with the processing and canning of fish and fish products. Canning machinery has been loaned to the school by the American Can Company, and with well-equipped chemical and bacteriological laboratories and a modern freezer and cold storage room, technological research will become possible under almost ideal conditions. Equipment will also be purchased for work with fish by-products.

It must be recognized, however, that to remain effective the School of Fisheries must maintain the closest contact with the biological research of conservation agencies on the one hand and with industry on the other. Seasonal work with research staffs which are developing the backgrounds for conservation, as well as experience with agencies that are actually regulating sport and commercial fisheries, provides training that has no substitute. The research agencies, as well as the industry, are also benefited by having available for temporary summer employment a group of men who at least have a theoretical background for specialized fisheries field work. With the new equipment for research, it will be possible for the faculty and students of the school to supplement the work of the various fisheries agencies by undertaking the investigation of problems, the solution of which will be essential to a final understanding of fisheries biology and technology, but which are usually considered to be outside the field of operations of a practical conservation agency or of the industry.

Opportunities for broadening horizons in fisheries are found in the foreign students who have come to the school from as far as India, China, Japan, Mexico, Turkey, Iceland, and elsewhere. If these students can return home after such training, imbued with an enthusiasm for conservation and an intelligent approach to exploitation of their fisheries resources, much will have been accomplished toward stabilizing one of the world's greatest supplies of food. Much can also be contributed toward international understanding through the mutual respect developed among the many nationalities in the informal atmosphere of the school.

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DISCUSSION

The paper was presented by Dr. J. L. Kask. In discussion, Dr. Hubbs said that limnology and oceanography were apparently not included in the school's work. He thought that a general training in fundamental science in a university was probably better than specific training in applied biology. Professor Yonge inclined to the same view, stating that training in fundamental science was the method followed in Britain. Dr. Kask agreed that training in fundamental science was desirable, but pointed out that certain technicalities, which were necessary and peculiar to fisheries, were taught at the school; two years on fundamental science were followed by two years' training in which the dynamics of fish populations were studied. Dr. R. C. Miller said that the school curriculum tended increasingly in the direction of fundamental sciences. Dr. Hubbs referred to the importance of a student's contact with practical work, many centres of fisheries activity being centred about the school.

Professor Yonge briefly outlined the work of the recently appointed Colonial Fisheries Office. Officers first receive training in fundamental sciences and later are taken on prolonged visits to various fisheries research institutes in Britain. Dr. Hubbs wished to know what was being done in the training of officers for administrative purposes at the Washington School of Fisheries. It was pointed out that the school aims to train for administrative, field and technical positions.

PROBLEMS IN FISHERIES MANAGEMENT FOR PELAGIC SCHOOLING FISH

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Division of Fish and Game

The subject of this paper has been chosen to limit the field to control of fishery industries dependent on pelagic schooling fish so that the supply of raw material will be maintained at a high enough level to assure at all times economic operation. Management as here used does not mean merely placing restrictions on the fishery. It strives for that ideal goal where a fishery is so administered that each year's harvest takes all available fish above the reserve necessary to insure a continued maximum yield in future years. Management methods commonly in use have not met the needs of pelagic fish populations, especially those which are caught in shoals or schools. The reason for these failures stem largely from the fact that schooling fish are frequently migratory and that the populations are subject to major fluctuations in success of spawn survival.

Because of these variations in spawn survival a school of thought has developed which holds that attempts at management of such fisheries are futile. Proponents of this theory believe that natural fluctuations are so great that any influence which man exerts directly through intensive fishing is minor and has no lasting effect on the fish population. If this be true, pelagic fisheries would be subject to small or great economic fluctuations from year to year or over a period of years, man would accomplish nothing by attempting to control the size of the catch, and fishermen should be allowed to take all they can when they can.

Opposed to this view are fisheries students who feel that natural fluctuations are not the only factors determining the abundance of fish, although also recognizing that many fish populations do experience large variations in survival from each year's spawn and for marine fishes these differences are largely due to natural causes over which man has no influence. In a relatively unexploited fishery there are enough fish in the population so that fluctuations caused by poor spawn survival for a few seasons will be masked by the presence of large numbers of older year classes. On the other hand, after a population has been fished intensively over a period of years the larger, older fish will have been caught off and when replacements of young fall below the annual loss through man's activities and through natural causes the fishery will suffer thereby. If failure in spawn survival extends over several seasons, a crisis may develop in the fishery. Such critical situations have occurred in the sardine fisheries of Europe, along the Pacific coast of North America and in Japan. The mackerel fisheries of the Atlantic coast of North America have also experienced major variations in success as have the mackerel fisheries of California. All the contributory causes which have produced fishing failures are not known, but in several instances lack of fish has followed a period of intensive fishing coupled with a low level of spawn survival. To avoid these major economic disturbances which come with a fishing crisis, advocates of fisheries management hope to control the annual catch so that a reserve stock of older fish will always be available to carry the fishery and the fish population over the seasons of poor spawn survival.

That certain basic information is necessary for such management is axiomatic. This basic information falls into three categories, biological, statistical and hydrographical. The biological involves those well-known studies which determine the age and rate of growth, the spawning season, size or age at first maturity, and locality of the spawning grounds. For a marine fish population, accurate delineation of the spawning grounds is frequently difficult and has not been done for most of our important fish populations of the Pacific, notably the several species of tuna. Another fundamental biological problem is the amount of migration which occurs between fishing areas or into and out of one fishing area. Again the tunas of the Pacific furnish an example. We do not know whether the intensive fisheries in the eastern Pacific and Japanese waters have or have not drawn from the supply which is now being tapped by the fisheries developing in the west and south Pacific. This question of admixture of populations must be answered for each species before management of a fishery on one or more fishing grounds can be justified or carried on intelligently.

In addition to biological information, statistical data are also essential to a management programme. Mortality and replacement rates must be known. These include fishing mortality, natural mortality and rate of recruitment. It is obvious that if a stable fishery is to be maintained, the average recruitment rate must balance the average total mortality rate. There can be a lack of adjustment for a short time but if total mortality exceeds recruitment for too long an interval, the fishery will be in a precarious condition. The only accurate statistical data available for a pelagic fishery are records of catch and the amount of effort expended by the fishermen to produce the poundage taken. If the fishermen are maintaining but not increasing total landings by fishing more units or by developing new and more efficient methods the balance between recruitment and total mortality is endangered and some adjustment of fishing intensity should be considered. This is where management should step in.

To obtain these statistical facts is not simple. Even the collection of accurate catch records necessitates an elaborate statistical system which must be undertaken by every government for its own nationals. These statistics must include not only the total catch but also records of the number of fishing units and the changes therein, as well as the amount taken by each individual unit.

Mortality rates may be calculated from the survival rates of each year-class as shown by age determinations or from returns from marking experiments or both. Recruitment rate can be determined from assessments of numbers of eggs, larvae, or young fish in each year-class. Where the critical point in survival occurs must be determined for each species, and suitable methods of measurement then developed.

A final requirement for an intelligent management programme is knowledge of the hydrography of the sea. Changes in currents, salinities, temperatures, and available food supply, not only determine the success of spawning, but also influence the availability of the fish to the fishermen. Major changes in availability could seriously upset calculations of return per-unit-of-effort expended by the fishermen and lead to false estimates of the size of a fish population, either too great or too small. In addition, to carry out a management programme the causes of spawning success or failure should be known and some means developed for estimating the amount of annual recruitment prior to the time when the young fish will first be exploited by the fishermen. A study of the hydrography of the entire Pacific is needed but is far in the future.

Some regional investigations have been started. These must be expanded and new studies initiated as rapidly as possible.

Assuming that sufficient biological, statistical and hydrographical data are available the method of fisheries management remains to be determined. Recently attempts have been made to approach this problem in new and relatively untried ways. These newer methods have met with opposition wherever attempted largely because the fishing industry does not realize that management must be such that catch will not exceed recruitment and that a successful management programme will of necessity curtail total catch when and if such relationships are out of balance.

First attempts at marine fisheries management were applications of freshwater methods to marine fisheries. Because so little was known about saltwater fish populations, man did not realize that the old ways would not suffice. Land animals and some freshwater fish protect their young, and closed seasons were developed as a means of protecting such forms during a time when they were especially vulnerable. It has been assumed that similar closed seasons would be beneficial to marine fish populations. In some instances this is true, but generally speaking this is not so. The herring fisheries of North America and Europe are largely prosecuted when the population approaches shore to spawn. But if fishing for these species were prohibited during the spawning runs there would be practically no fishing, so even here a closed season is not the answer. Most of our marine fish, on which the major fisheries of the world depend, spawn in the open ocean and produce planktonic eggs. For conservation purposes there is, therefore, no more point in protecting such fish during the spawning season than during any other month in the year. The total number removed from the population is the same in either case.

In many instances man has deluded himself into thinking he is maintaining the supply of fish, whereas he is only inconveniencing himself and doing nothing for the fish population. Many members of the fishing industry and many administrators believe sincerely that the closed seasons they advocate really result in benefit to the fish, whereas they are merely handicaps to the industry or are set for economic reasons. Basically a closed season for pelagic fish can serve as a management tool only when it is sufficiently restrictive to cut total fishing to the point where overall production is limited.

Closed areas also are frequently ineffectual. Many marine fish undertake extensive migrations and move freely from area to area. Although protected on one fishing ground, the same fish become vulnerable on another. Exceptions to this are nursery grounds where young fish predominate and closure of such grounds will protect the young when they have little economic value and will not handicap the fishery for the larger, older fish.

Size limits have also been applied freely to saltwater fishes. The success of size limits depends on the fishing method. Where fish are taken in gill nets, a size limit is practical and can be regulated through mesh size. To a limited extent a hook and line fishery can be regulated by hook size. Trawl fisheries can also be managed by mesh size restrictions. Many of our fisheries, however, depend on purse seines which are set on schools of fish and undersized fish cannot be avoided. For such a fishery a size limit is impractical. Even where a size limit does protect the fish up to a certain size, an intense fishery may hold the population at such a low level that legal-sized fish are not sufficiently abundant in the population to carry the industry over years of failure in spawn survival. Hence size limits can do little to stabilize a fishery.

Future management programmes should, therefore, be based on a frank realization that success will mean inconvenience to the industry and a sacrificing of some immediate gain for future stability. The most direct management method is a limitation on the amount of fish which may be taken within a given time interval. This is frequently referred to as a seasonal or yearly bag limit or quota. Given sufficient biological and statistical data it is possible, theoretically at least, to determine how much man can remove from the population each season and still leave adequate numbers to maintain the fishery in the ensuing years. All too frequently, however, adequate information is not available and the bag limits must be set by a trial and error process. The method of control must be flexible enough to permit adjustments from season to season as abundance levels change.

Such fluctuating seasonal or yearly bag limits can be successful only if based on adequate biological, statistical and hydrographic data. As the drain on all fisheries in the Pacific increases, the urgent need for scientific data increases, and all governmental bodies concerned should immediately initiate or expand their fisheries investigations. These investigations must be set up to provide accurate catch statistics and life-history data for the species involved and information about the chemical and physical oceanography of the Pacific, about the food supply and about the physiological reaction of the fish to changes in these factors.

For most of our fisheries there is overlapping in the territory and in the problems involved. Thus all phases of these investigations must be co-ordinated and information freely exchanged. Only through such united efforts can we hope to solve the management problems of the Pacific fisheries. The Pacific Science Congress should become an important agency in this co-ordination.

PHILIPPINE FISHERIES TODAY AND TOMORROW

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The Philippine people are a part of the great rice-eating population inhabiting the eastern and southern coastal plains of Asia, and the large islands offshore. It includes the people of Japan, the southeastern part of China, Siam, Malaya, Indo-China, Burma, much of India, and all the islands from Formosa to Ceylon.

Like the rest of these people, the Filipinos would rather eat rice than wheat or maize, and for their protein food they prefer fish to any butcher's meat. This is something that most people of European descent cannot seem to understand. They cannot seem to comprehend that there are whole populations who would rather eat fish than beef or mutton. When a working crew of 50 or 60 Filipinos threatens to strike if fed beef oftener than once a week, the average white man is both puzzled and astonished.

Equally alien to the minds of English-speaking whites is the fact that fish and the fishing industry in the Philippines and other rice-eating countries are the equivalent of the meat and livestock industries in Australia, the United States, and Canada. It is evident therefore that fish and the fishing industry are matters of prime importance in the Philippine national economy. Rice is the item of first importance and fish the second item in the national economy. Although these two factors do not figure heavily in bank clearings or custom house statements they are really the ones that make the national economy function. They keep the people in health and strength, when supplied in adequate amounts. Along with some vegetables and fruit they form a balanced diet.

Before the last war Filipino markets were fairly well supplied with fresh fish at a reasonable cost. The supply of dried fish was less ample, while its quality was often very poor. The bulk of the catch was obtained by native fishermen, who for the most part used the methods of their ancestors. The chief methods were fish corrals, hook and line fishing, bobos or woven traps, and the use of various kinds of nets. Their bankas, or dugout canoes, were moved by either paddles or sails, or both. Even the largest lacked deck room and cargo space, and had no keel. Fishermen using them could never go more than a few miles from shore. The catch was marketed fresh and in the round, ice being seldom used and fish were rarely dressed. When the catch was large the surplus was dried, if possible.

A large part of the market supply, not only in the Philippines but in all Malayan regions, was taken by Japanese fishermen. They introduced the "muro Ami" or Caesio net method, using ocean-going launches. Some years later they introduced beam trawl fishing. They were able to go to sea in all kinds of weather, except during an actual typhoon. Their catch was packed in ice and delivered to the markets in excellent condition at moderate prices.

The Japanese fishermen filled a public need which the native fishermen did not meet. As a result in a few years they held a dominant position in the Philippines markets and also those of Singapore, Batavia, and many other cities in that region. In the Philippines they brought fish from places as much as 750 miles away, and for the Singapore market from places more than 2500 miles distant. For more than a decade I urged Philippine fishermen to adopt the muro ami method, but in vain.

The war destroyed most of the fishing fleet, both native and Japanese, and made it impossible to supply the demand for fish. Of course there were no more Japanese fishermen and the entire fishing industry was left badly disorganized. Motor launches, trawlers, and most of the large native bankas had been destroyed during the war so that the fishermen in many places could no longer function. The supply of fish at Manila and other centres of population was altogether inadequate, and the cost of good fish rose far beyond the means of most people. At the same time in fishing centres remote from cities, and without transportation, the price was low. In 1948 the finest kind of fish could be bought from the Bajaus and Samals in the Sitankai area at the extreme southern tip of the Sulu Archipelago at 15 to 35 centavos a kilo, but by the time such fish reached the Manila market they were priced at a peso fifty to three pesos a kilo.

Filipino fishermen and business men, together with some Americans, have struggled hard to re-establish the industry, and are meeting with some measure of success. Many bankas have been built and equipped, and many fish corrals are once more in operation. More than fifty beam trawlers are operating in Manila Bay and at least half a dozen more are at work elsewhere. There are too many trawlers dragging Manila Bay, and for the good of the industry the number should be reduced to not more than 25 or 30, if the productivity of Manila Bay is to be maintained. Several otter trawlers are fishing about the Visayan Islands, particularly Panay and Samar, while others are being added to the fleet. In addition, more than three dozen motor vessels, with capacities ranging from twenty to about 100 tons, are engaged in bringing fish from various parts of the Islands to the Manila market. Most of these fish are bought from fishermen, who catch them in corrals, by hook and line, by spear, and by nets. Unfortunately some operators obtain cargoes by using dynamite themselves, or buying fish from dynamiters. This is a very wasteful and destructive method of getting fish. Besides the direct damage done to fishes and reefs, not more than half of the fish killed are actually collected. The war left large quantities of high explosives available to many unscrupulous people, so that they are used everywhere. Any day one may see dynamiting on the Manila waterfront and in Cebu harbour. As yet the government has done very little to curb this vicious practice.

The Philippine fish fauna is an integral part of the rich East Indian area, which has the most diversified and largest fish fauna in the world. In my recently completed Check List of Philippine Fishes, 2,145 species are listed. Most of this great number are edible, and several hundred kinds are found in the markets in their proper seasons. While many occur in limited quantities, many kinds occur in large to very great quantities at certain times of the year.

Foremost in importance in Philippine fisheries is the sardine group, especially the migratory species which come during the south-west monsoon. There are 18 species, belonging to the genera *Sardinella* and *Harengula*. All of them are eaten more or less, but the bulk of the catch is limited to three or four species, the most important being the well-known oil sardine, *Sardinella longiceps*, known as tamban in Tagalog. Other important sardines are tunsoy, *Sardinella fimbriata*, and lapad, *Sardinella perforata*. Many sardines are eaten fresh, but the bulk of the catch is dried. Small lots have been canned here and there at various times, particularly in Busuanga, Samar, and Leyte, but these have had no commercial importance. A regular cannery was started at Madridejos, Bantayan Island, but the war and finances crippled it. Several million pesos worth of canned sardines are imported annually, so that there is an excellent market in the Philippines for a clean product that can be sold at a very low price.

The most important single fish in the Philippines is bañgos, *Chanos chanos*. The fry of this large vegetarian pelagic fish occur in very great numbers on shallow sandy shores throughout the Philippines. They are collected from February to October, but mostly in March, April, and May. The fry are reared in salt water ponds, mainly around Manila Bay. However, bañgos ponds are in operation from the shores of the Gulf of Lingayen in La Union and Pangasinan Provinces, Luzon, southward to Panay, Negros, Cebu, and various parts of Mindanao. Altogether the ponds represent an investment of about a hundred million pesos, with an annual crop valued at about twenty million pesos.

Certain migratory fishes of the family Carangidae occur in large schools and are the object of important fisheries. They are caught in fish corrals, by beam trawl, and by various kinds of nets. The scads, crevalles, big-eyed scad, and round scad are most important. Similar in habits and schooling and taken by the same methods are the Japan mackerel and the much more abundant tropical mackerels of the genus *Rastrelliger*, with at least two species in Philippine waters. All the above are eaten fresh and are also salted and dried. All could be canned and would be a cheap wholesome food, if canning costs were kept down.

Eight species of tuna and bonito occur in Philippine waters. Nearly all are found in large to very large schools. The commonest are the yellow-fin tuna, *Neothunnus macropterus*, the yaito tuna, *Euthynnus yaito*, the oceanic bonito, *Katsuwonus pelamis*, and the least tuna, *Kishinoella tonggol*. In addition to the tunas and bonitos, are two species of *Auxis*, or frigate mackerel, which likewise come in large schools. All the tuna group are caught in fish corrals, by long line, and with nets, while a few are taken by hook and line. In deep bays these fish come close in shore and are taken in fish corrals set in water up to a depth of 200 to 300 feet.

Reef fishes of good to excellent quality occur throughout, being particularly abundant on the vast reefs and feeding grounds of the Sulu and Celebes Seas. They include a great variety of families and species, ranging from medium to very large size. The more important reef fishes are the groupers or sea bass, the snappers, the grunts, the theraponids, the lethrinids, the scolopsids, the sparoid fishes, and a variety of runners, jacks, and other members of the Lutianidae or snapper family, and Carangidae or trevally family.

Schools of Caesios, surgeon and nose fishes, and of siganids are found on reefs throughout, often in very considerable numbers. With the departure of Japanese fishermen these are no longer taken in quantity, except where dynamite is used. The only legitimate way in which these fishes can be taken by the ton is by the Caesio net or "Muro ami" method already mentioned. The quantity which can be taken with bobos or basket traps is very limited, and they cannot be caught commercially with hook and line.

Many other kinds of fish are the basis of locally important fisheries, some of which could be greatly expanded. On the Ilokano coast the Japan hairtail is caught in small numbers. This fish reaches a length of one and a half to two metres, and makes a superior quality of dried fish. The fishery could be intensified with beneficial results.

Flying fish are caught in a small way in many localities, but there is no regular fishery for them except on the coast of Cebu and western Samar. Flying fish abound in Philippine waters, and could be taken much more extensively than they now are.

Marine catfishes of the genus *Arius* are taken in Manila Bay and San Miguel Bay by fish corrals, by trawl, by bobos, and by nets. They could be taken by the same methods in many other localities where they are not now caught in quantity. They are not of the finest quality, but are good edible fish that find ready sale.

Mullet fisheries are important in several localities, large numbers being caught when the fish return to the sea for spawning, at the outlets of lakes and in river mouths. Many are also taken from bañgos ponds. Mullet, at least of certain species, are well adapted to pond culture, and are a promising field for investigation.

At certain times the fry of half a dozen species of gobies enter the mouths of rivers in northern Luzon and are the object of a very important fishery. Each species of goby, of course, has its own time of migration. The fry are caught just before they enter fresh water, or very soon after they are in the river. Put up with alternate layers of salt and fish, they form bagoong or guinamos, widely used throughout the Islands, adding protein and relish to rice. On certain coasts vast shoals of siganid fry approach the shore, and are taken likewise to make bagoong. The value of the kinds of fry thus taken, when converted into bagoong, is a million pesos or more annually.

The catch of shrimp is large and seems capable of expansion. At present the chief sources of supply are Manila Bay, San Miguel Bay, the bangos ponds, and trawling west of Samar. Trawling in other parts of the Islands should greatly increase the supply. Shrimps are the most profitable catch made by trawling in Philippine waters.

There are important fisheries of crabs and other crustacea, and of many kinds of edible mollusks. The culture of oysters is one field of great promise, though the pollution of Manila Bay water presents a difficulty which must be solved if the industry is to grow. There is an important fishery of button shells, both the Turbo shell and the top shell, as well as the gold lip pearl oyster. All of these can be developed on a larger scale than at present.

There has never been any real competition from outside the Islands in the Philippine fresh fish market. Occasionally when the Hong Kong market was glutted a few tons of frozen fish were shipped to Manila, but never were an important factor. Small lots of frozen salmon, and sometimes other fish, were imported to cater to those whites who are scandalized at the idea of eating "native food", but such importations come under the class of luxury items and are of slight commercial importance.

Until the First World War large quantities of canned salmon were imported from the United States. After that war, salmon was replaced by canned sardines from California, importations rising to a value of more than six million pesos annually. A few years later canned sardines from Japan pre-empted the Philippine and all Malayan markets. At the present time California sardines are again in the market, but they cost four times their former price and are beyond the means of most Filipinos. There is no likelihood of any foreign competition in Philippine fisheries or fish markets in the visible future. All the countries in the western Pacific are having a struggle to provide food enough for their own nationals.

In former years some dried fish was imported from China, occasionally, but the reverse process occurred much oftener, in fact most years. Whenever there was a favourable season and a large catch of sardines in the Visayas, considerable amounts of dried sardines were exported to China, mainly, if not entirely, to Amay, Hong Kong, and Canton. At present prices are entirely too high to permit any export. Even if prices were much lower it is doubtful if any dried fish of good quality would be exported, since the local market is still inadequately supplied.

Philippine fisheries still lack much of having attained their full development. In fact, little more than a beginning has been made toward utilizing Philippine aquatic resources. The director and division chiefs of the Philippine Bureau of Fisheries are leaders in the difficult process of modernizing and expanding the Philippine fishing industry. The Japanese destroyed their vessels and equipment, offices, libraries, laboratories, collections, and pilot cannery, so that when peace came they had nothing with which to resume work. However they still had their training acquired in the United States and Japan, their professional knowledge and skill based on their lifetime of work in the Philippines, and their indomitable spirit. They are far better equipped to expand Philippine fisheries than any people imported from the United States, who are ignorant of the tropics, and of Philippine fishes, fisheries, and fishermen, as well as Philippine economic and social conditions. Imported fishery workers are not qualified to pass judgment upon Philippine matters or to attempt the improvement of Philippine fisheries until they have studied local conditions for several years and learned the native methods. If a small part of the money that has been spent lavishly by Americans ignorant of the Philippines had been placed in the hands of the Philippine Bureau of Fisheries important results would have been quickly secured.

Some of the native fishing methods are excellent and cannot be improved upon, but they are all for fishing in shallow water or along shore. The huge increase in population during the past twenty-five years has made such demands on shore fisheries that they cannot meet them without grave risk of seriously depleting the fish population.

New methods must be introduced for the capture of pelagic and semipelagic fishes by deep sea or offshore fisheries. This must be done without discarding old methods of proven excellence. Owing to the prevalent physiographic conditions, the deep seas, and narrow strips of continental shelf where there is any at all, and the limited area suitable for trawling this method of fishing cannot be greatly expanded without going outside the Philippines.

Philippine fishermen are weatherwise, with a profound knowledge of tides, currents, and the feeding and schooling habits, and migrations, of fishes along the island coasts. They are handicapped by their boats, since even the largest are but modified double outrigger dugout canoes, unsuitable for pelagic fishing. The few exceptions already mentioned, the motor trawlers and fish transports, are not engaged in pelagic fishing, and the lipa of the Sibutu Islands is only used for reef fishing.

Before there can be any great improvement in the Philippine fishing industry it will be necessary to help the fishermen acquire keel-built ocean-going launches or fishing boats, with appropriate gear, and to train them to develop off-shore fishing. The most feasible way of doing this would seem to be through government sponsored co-operative associations. If necessary, the government should subsidize such enterprises until well established. Emphasis should be placed on small boats not more than 35 or 40 feet in length, and manned by two to five men. Such craft would allow the industry to remain flexible, without over specialization, and the inordinate expense and overhead that accompany a highly specialized method of fishing. At the same time there would be a real need for a few larger boats capable of fishing from thirty or forty to two hundred or more miles off shore. There could be one to several mother refrigerator ships as need required, each with a fleet of small motor boats to catch and bring fish to it.

At the present time in certain places Filipino fishermen fit outboard motors to their double outrigger bankas and install a couple of 1,000 to 2,000 candle power lamps and troll for fish at night. In this way large catches are often made of Spanish mackerel or tangigi, wahoo, barracuda, dolphin, guntol, and other large valuable free swimming fishes. Their catch is loaded on trucks and taken directly to Manila. Manifestly this method can only be used where good marketing facilities, including good roads, are available. A step beyond this method would be that indicated in the preceding paragraph, and this step should be an easy one for the fishermen already accustomed to spending the night in trolling a few kilometres off shore.

With the use of small motor boats of the type indicated, fishing could be conducted systematically at least 25 or 30 miles off shore. With the larger vessels mentioned, fishermen could enter fishing grounds little or not at all worked. Only Japanese poachers from Formosa have ever properly fished the extensive grounds among the Batanes and Babuyanes Islands north of Luzon and off the north-east coast of Luzon. A 3,000-ton mother ship, accompanied by a fleet of sampans, would anchor in the region and refrigerate the fish caught by the smaller boats. Their catch was mainly oceanic bonito and yellow fin tuna, though other tunas and swordfish were also taken.

For a part of the year Filipino fishermen could work in this region and also for 300 miles southward along the east coast of Luzon. They could catch various members of the tuna family, mackerel scad and other migratory fish of the Carangidae, Japan mackerel and mackerel of the genus *Rastrelliger*, Spanish mackerel and wahoo, swordfish, marlin, sailfish, and dolphin.

From Davao, Mindanao, vessels could strike out into the Kuro Siwo and fish northward, while boats from Tacloban, Leyte, and Legaspi, Luzon, could work the areas nearer to those places. All would follow the northward migration of bonito, tuna, mackerel, carangids, and other fishes. In search of the same fishes they could also strike out eastward into the open Pacific, toward the Pelew Islands. There is reason to believe that much of the region between Mindanao and the Pelew Islands, and north of New Guinea, is heavily populated by various members of the tuna family. This is in agreement with my own observations between the Pelews and Davao, and statements from the Fishery Station in the Pelews between my visit there and 1939, when I last talked to scientists from there.

In the words of Dr. H. J. Deason, Chief of the Office of Foreign Activities, U.S. Fish and Wildlife Service, "the Sulu Sea is swarming with fish", a fact established centuries ago by the Samal and Visayan fishermen who live beside its fertile waters. The statement that the "Sulu Sea is sterile", made by a recent arrival, is made ridiculous by the large catches and the quantities of first class fish brought to Manila from the Sulu Sea. If they had suitable market outlets the Bajaus, Samal, and Visayan fishermen could increase their catch many fold. At present if they increased their catch they could not dispose of it much of the time.

Rich as it is, the Sulu Sea is not as good a fishing ground as the South China Sea. It is a region almost untouched by fishermen, and contains great areas in its southern part that are suitable for trawling, as shown by David Stead. Thus far only one or two Japanese trawlers have ever worked there. The great schools of sardines that enter the Philippines through the Straits of Balabac during the southwest monsoon have never been traced to their breeding grounds in the South China Sea. West of Palawan is a great uncharted area of shoals, banks, and reefs, said by the few people who have ventured into it to be a wonderful fishing ground where schools of tuna, bonito, scads, and a great variety of reef fishes occur. The migratory schooling fish range northward at least as far as the latitude of northern Luzon. Great schools of squid occur west of Luzon and Mindoro, according to Japanese fishermen who brought back a sample cargo.

The Japanese cannery set up in 1940 at Banguey Island, south of Balabac Island, had a capacity of 75,000 cases per annum. Its fish were caught in the Sulu Sea and in the adjacent South China Sea. Apparently this was the only attempt ever made to use the fishery resources of the South China Sea outside the coastal waters of Palawan and other Philippine islands, and of China and Indo-China. This great and immensely rich area is waiting for the development of a modernized Philippine fishing fleet.

The first and most important function of the Philippine fishing industry is to supply the markets with ample quantities of fresh fish in first class condition, at prices within the means of the vast bulk of the people. Next to this in importance is the production of plenty of first class dried fish. This is something that should be pushed with great vigour by those in authority. It is a matter of far greater importance to the Philippine economy than any tuna canning industry, since it means supplying the common people with cheap and wholesome food. The first step toward attaining this goal is the production of first class salt at a price the fishermen and fish driers can afford. It will be a long time before the Philippine market for good dried fish is satisfied, and there is no danger of an over supply. Any surplus can always be sold in China and Malaya.

With the fisheries developed along the lines indicated, or otherwise modernized, the fresh fish market will be amply supplied and the demand for good salt fish will be satisfied. Then surplus fish may be utilized for canning. Canned tuna would be too expensive for general consumption in the Philippines, but would form a very useful export product. It would serve the double service of obtaining greatly needed foreign exchange and of diversifying industry, thus giving an additional outlet for labour. Sardines, bañgos, mullet, mackerel, mackerel scads, and any other fish caught in quantity could be canned for local consumption, provided that costs are kept down so that Filipinos can afford to buy the product.

Discussion of river and lake fisheries has been omitted, though they are of considerable local importance in many places. Freshwater fish ponds and the culture of gurami and sipat Siam are of rapidly growing importance. Gurami, introduced by me in 1927, are now cultivated in three-fourths of the provinces. Sipat Siam, introduced by Dr. Eduardo Quisumbing in 1938, is extensively cultivated in Central Luzon, in the vicinity of Manila.

Philippine fishes, like all other fishes, pay no attention to man's artificial boundaries. In a few hours they may be under the jurisdiction of the British, the Dutch, and the Philippine governments. In addition, the governments of China, Indo-China, Siam, and Malaya are also vitally interested in the fishery problems of the South China Sea. As long ago as 1926 in my address to the Science Congress held in Tokyo I urged the formation of an international commission to study the migratory fishes of the region, with power to issue regulations for their protection and conservation. At the Science Congress in Java in 1929 I presented a paper urging the same thing again, along with a plan for the implementation of the idea, but again nothing was done.

In 1948 a meeting was held in the Philippines to discuss food problems in connection with the United Nations programme. Discussion of fisheries was attended by representatives of the United Nations, British North Borneo, China, Dutch East Indies, India, Indo-China, the Philippines, and the United States. It is hoped that from this preliminary meeting an organization may result which can make a united and thoroughly co-ordinated attack upon the many problems affecting the joint fishery interests of the countries bordering the South China Sea, the Sulu Sea, and the Celebes Sea. Such an organization could well be modelled after the European Councils for the Investigation of Marine Fisheries. Membership should be limited to natives or Europeans long resident and familiar with the people, languages, and social organization, native methods of fishing, and the fishes of the region.

During the twenty-nine years I have been associated with Philippine fisheries, one of the most astonishing things encountered has been, and still is, the swarm of people who want to go into the fishing industry. They are a heterogeneous lot, of all sorts of social status, seldom with adequate financial backing, Filipinos, Americans, Germans, English, Spanish, and other Europeans, but never Japanese or Chinese. They have but one thing in common, a colossal and incredible ignorance of all matters pertaining to fish and the fishing industry.

Attracted by the extraordinary prices paid for fish in the Manila market after the war, numbers of inexperienced Filipinos and Americans went into the fishing business. Most of them bought their fish from fishermen in outlying regions and brought them to Manila by launch, train, and even by airplane. Some of them did well for a time, but eventually most of them lost heavily or went broke. Only a few knew what they were about, were able to cut costs, and are still in business.

For those qualified by knowledge and experience there are good opportunities to engage in some phase of the fishing industry in the Philippines, provided they have sufficient capital to finance themselves. Very few who have started in the fishing business have had anything like enough capital to survive fluctuations in the market. One prerequisite to success is experience in dealing with and handling Filipino fishermen and labour. Anyone operating in the Sulu and Celebes Seas must be able to deal with Mohammedan, pagan, and Christian fishermen.

The present population of the Philippines is approximately 18,000,000 and is increasing at a very rapid rate. Another twenty-five years and it will be more than 25,000,000. If the fishing industry is properly developed with sufficient attention to pelagic or offshore fishing, the population will be better fed than it is today. This assumes that the cultivation of gurami and sipat Siam receives due and proportionate development. Then garnering the resources of the islands north of Luzon, harvesting the fishes of the Kuro Siwo along the east coasts of the Philippines and ranging far out into the Pacific, and securing the fishes and other marine products of the South China Sea will ensure ample supplies of both fresh and salt fish and plenty for a profitable canning industry.

PHILIPPINE BANGOS CULTURE: A SUCCESSFUL METHOD OF SALT WATER POND CULTURE

By Albert W. C. T. Herre, School of Fisheries, University of Washington, Seattle

In all countries where rice forms the basic carbohydrate food of the people, fish have a dietetic and economic importance scarcely comprehensible to the people of regions where maize, wheat, rye, or oats form the bread of the people. That is because all rice-eating populations rely upon fish to furnish them protein, an essential constituent of all diets.

To this general statement the Philippines are no exception. Nearly all Filipinos consider themselves inadequately fed if they do not have fish to go with their rice at least once a day. My recently completed Checklist of Philippine Fishes, catalogues 2,145 species thus far known within the confines of the Philippine Islands. It is safe to say that of this very large number at least 500 kinds are taken for human consumption some time during the year. As a matter of fact the number may be much larger than this. No one knows how many kinds of fishes are to be found in the Philippine markets, but in the course of a year the markets of such cities as Manila, Cebu, and Zamboanga may contain at one time from a hundred to a hundred and fifty species, and in twelve months may have a total of twice that many. Of course some of them occur in very small numbers or are rare and infrequent in the markets. Other fishes never get into the markets at all, as anglers or fishermen take them solely for home consumption. At the same time a good many kinds are taken in large to very large quantities and are of great importance in Philippine economy.

The most important group of fishes in the Philippines is that of the clupeoid fishes, using that term in a wide sense. It thus includes herring and sardines, and all their allies.

Of all the great number of Philippine fishes, the most important is one unknown in Europe, the United States, and Canada, but of very widespread occurrence in Indo-Pacific waters. It is *Chanos chanos* (Forskal), the only living representative of the genus *Chanos* Lacépède, and of the family Chanidae. This fish, best known as bañgos or some variant of that name in the Philippines, is called bandeng in Javanese, bandang in Malay, and awa in Hawaiian.

It is a large brilliantly silver fish, having the general appearance of a large cyprinid. Bañgos reach a length at maturity of nearly a metre and a half, becoming very thick and bulky anteriorly. The colour in life is brilliantly silver over all, the back brilliant glossy blue or bluish olive. Bañgos are swift and powerful swimmers, the deeply forked tail and strong caudal peduncle enabling them to travel with great speed. Adults are called "lumulukso" in Tagalog, the word meaning leaping, and well do they deserve the name. A bañgos two-thirds of a metre long can leap easily out of the heart of a fish corral, soaring over walls four metres out of the water, and landing twelve metres or more away. In the open sea adults have been observed repeatedly to leap vertically to a height of more than eight metres.

Bañgos are vegetarian, all but the very young fry living on filamentous green algae, or "lumut", belonging to the genera *Spirogyra, Enteromorpha, Vaucheria, Cladophora, Oedogonium,* and *Chaetomorpha.* Off Cagayan de Misamis, Mindanao, fishermen sometimes catch adult bañgos at depths of about 100 metres by using a certain small tough jellyfish as bait. Otherwise they are not known to eat anything in the sea but lumut.

Bañgos frequently enter freshwater rivers and if there are any large freshwater lakes but little above sea level they ascend to them and remain there until two-thirds of a metre long, or more. Lake Bombon and Lake Bato, on Luzon, and Lake Naujan on Mindoro, are the most important lakes for bañgos in the Philippines. The fish never become sexually mature in lakes and rivers, even in Lake Bombon which is more than 27 kilometres long and 20 kilometres wide, with a maximum depth of nearly 200 metres. Practically no fish ever escape from Lake Bombon and very few from Lake Naujan. This is because their outlets are closed by fish corrals of such size and strength that even the most powerful lumulukso cannot leap out of them.

Bañgos become sexually mature only in the open sea. They have been kept in fish ponds for as much as six years, and it is said eight years, without developing sexually.

The flesh of bañgos has a mild and delicate flavour. Those grown in fish ponds and commonly seen in the markets, are harvested when but a few months old and are filled with an excessive number of fine bones. Owing to the large size of the adults the fine bones are little evident, and therefore large full grown bañgos are much esteemed throughout the Islands. It is due to the great number of minute bones that young bañgos are little desired except among the Tagalogs and Pampangos, though appreciation of their good qualities is becoming much more widespread in recent years.

It is not the catch of bañgos in the sea that has made them the most valuable fish in the Philippines, for the take of mature fish is too small to be a factor of any importance in Philippine economy. It is their culture in saltwater fish ponds, and to some extent in brackish water ponds, and the amazing tonnage of food produced thereby, together with the ability to supply them to the markets when no other fish are obtainable, that gives them their unique and pre-eminent position among fishes important in the Philippine domestic economy. During the typhoon season bañgos are often the only fish to be found in the Manila markets. They can be obtained readily from the ponds when it is impossible for fishermen to go out in their boats.

Bañgos have a rare combination of valuable characters, and are probably the most desirable of fishes for culture in brackish or salt water ponds. Their vegetarianism and entire absence of cannibalism, the ease with which large numbers of fry may be secured, the rapidity of their growth, the cheapness with which they may be fed, and the delicate flavour of their flesh, are features not found in such a happy juxtaposition in any other fish.

Bañgos have been cultivated for many centuries, perhaps for a thousand years or more. Bañgos fish ponds are mentioned in Javanese laws codified about 1400 A.D., and naturally must have been in operation for a long long time before that. They were cultivated in a primitive manner in Madura Island and the Hawaiian Islands hundreds of years ago, while their cultivation in the Philippines is said to antedate the coming of the Spanish.

Apparently adult bañgos live in small schools in the open sea. They are believed to spawn on or near quiet shallow sandy coasts, as the fry are found in vast numbers along shore in such places. The fry enter saltwater creeks and shallow places with the incoming tide, and go out with the ebb tide. Formerly it was believed that bañgos spawned from the latter part of March until early June, with the peak of activity in April and May. It is now known that spawning is going on somewhere in the Philippines from February to November, and it is probable that some spawning occurs every month in the year.

Bañgos are very prolific, the number of eggs laid by a single female less than a metre long varying from about 3,000,000 to 5,700,000 eggs. Very large old females are estimated to have more than 7,000,000 eggs. Only the codfish is positively known to have a larger number of eggs.

As soon as hatched the fry, known as kawag-kawag in Tagalog, are found swimming in immense schools along shallow sandy shores and entering estuaries and tidal creeks. Their capture is an important industry in certain places, particularly along the south coast of Batangas Province. With the growth of the industry, a greater supply of fry became necessary, and they are now shipped to certain towns on Manila Bay from suitable localities, ranging from the Ilokano Provinces of northern Luzon to various places in Mindanao. They come by truck, railroad, and steamer, but the bulk still continue to come by sailboat.

The fry are caught with very fine meshed nets. They are then 10 or 12 mm. long, very slender and transparent. As soon as possible they are placed in low, wide-mouthed, unglazed jars called palyok or palayok, of about 15 or 30 litres capacity. About 1,500 to 2,000 fry are placed in a 15 litre jar, and 3,000 to 3,500 in a 30 litre jar. The mortality of fry while in transit in the palyok varies from 5 per cent or 10 per cent for those shipped short distances to 25 per cent or more, where they come hundreds of kilometres and receive little or no care.

The fry are usually consigned to or purchased by men who make a business of handling and rearing them up to the fingerling stage. These men make a business of supplying fish pond owners with fry or fingerlings.

Other kinds of fishes are often found mixed with bañgos fry. As far as possible they should be removed, for some of them soon become very injurious. Certain kinds are very difficult to detect, for they too are very slender and transparent and look astonishingly like bañgos fry. In spite of this, the men who make a business of handling fry become amazingly skilful in separating the harmful species from bañgos.

Long ago marine fish ponds were made by walling up the narrow entrances of inlets and small bays. The fishes borne by the incoming tide were allowed to enter freely, after which the opening was closed by a gate or a rock wall. In either case, water could enter and flow out, but fish of any size were barred from passing. Once a year the fish were harvested, and anything obtained was looked upon as a gift from God. In the East Indies and Philippines this method was superseded centuries ago by the excavation and walling up of ponds in nipa swamp lands, but the stocking of the ponds continued to be a matter of chance. The careful selection of bañgos fry, and the attempt to cull predators from them so that the ponds would contain very few fish beside bañgos, is apparently a development about ninety years old in the Philippines.

The centre of bañgos culture in the Philippines is about Manila Bay, where the value of the ponds is between 30,000,000 and 40,000,000 dollars. Bañgos ponds in other parts of the Islands are worth at least 10,000,000 dollars more. To replace them at the present time would cost approximately three times as much.

Clay is the proper soil for fish ponds. It holds water best and is also best for the algal growths on which bañgos feed. The best land ordinarily available for bañgos ponds is nipa swamp land, although ideally peat or tule land is best. Mangrove swamps are not so desirable as the hardwood mangrove trees are often quite large, are difficult to cut, do not die readily, and to remove their stumps is a laborious and expensive task.

A bañgos pond should be located near a deep tidal stream so that an ample supply of fresh sea water may be secured at all times. Places otherwise desirable may have a lack of good sea water during the dry season. The pond must also have readily available cheap transportation at all times, giving it easy access to a good market.

After selecting a site a strong well-built dike must be erected around the entire area of the pond. The size of a bañgos pond depends upon a great variety of circumstances and may vary anywhere from a fraction of a hectare to fifty or even a hundred hectares.

A system of fish ponds all belonging to one person or under one management may contain 500 or more hectares, up to 2,800 hectares, as for example the plant of the National Food Corporation near Capiz, Panay.

The base of the dike should have a minimum breadth of four to five metres, and should be high enough to reach well above the highest tides of the year or the greatest floods of the rainy season. The least breadth at the top should be a metre. Some of the best ponds have the top of the encircling dike broad enough for a cart or automobile to pass along freely.

The main dikes are made of soil taken from the inside of the pond, next to the embankment. A bañgos pond should never be deeper than the river or creek beside it, but on the contrary its deepest part should be slightly above the stream at its outlet, during ordinary low tide. Where the soil has been removed to make the embankments the pond is, of course, deepest. There it may be a metre and a half deep, more or less, but the greater part of a stock pond may be very shallow. Large areas may be about half a metre deep, with deeper areas where ditches are dug to bisect a pond, or where parts of creeks are included. In building the dikes all stumps, roots, logs, and limbs of trees should be removed. If allowed to remain their decay causes holes which allow water to escape from the pond. Dikes must be patrolled regularly to prevent breaks, stop holes made by crabs or other animals, strengthen weak spots, and to guard against the effects of settling. Often a dike must be protected by walls of stakes or piling, to guard against the effects of waves or currents. In many places mangrove trees, or nipa or coconut palms are planted along dikes.

A bañgos pond must be partitioned to form several compartments, or else must be composed of several connected ponds operated as a unit. There should never be less than four compartments, and in large pond systems there are necessarily many compartments. The exact number needed will depend on circumstances and adjustments must be made for the needs of each individual system. The compartments vary in size and depth, since they are occupied by fish of different ages and sizes. In any event, one of the compartments should be very much larger than any of the others. In small bañgos ponds the largest pond should be as large as all the rest put together.

The partition dikes are low, usually narrow, and are not strong like the outer wall. They do not need to be more than a metre wide at the water level, and somewhat less at the top, while the smaller ones may be only wide enough to provide safe footing at the top.

Well built gateways are necessary to control the intake and outflow of water, and the movement of water from one compartment to another. The principal gates should be of concrete, but the gates to allow water and fish to pass from one pond to another may be of wooden construction, small and simple. The main gates should each have three sliding doors moving vertically, so that when all are in place they enclose two spaces within the gate. The central door is of closely fitting movable slabs placed edge to edge, and made of very hard durable wood. By them the movement of water is regulated or stopped altogether. At the entrance and exit of the gate are sliding doors of closely woven split bamboo.

The most important division of a bañgos pond is the nursery pond, in which the very young fry or kawag-kawag are placed. The preparation of the nursery pond is a tedious, delicate, but most important task since its condition determines the success or failure of the whole enterprise. Bañgos fry are not only very delicate, demanding relatively cool and fresh water, but their food is altogether different from that of the older fish.

They feed upon a plant complex that under proper conditions forms a mat over the floor of the nursery pond. This is known as lab-lab in Tagalog. The compound microscope shows lab-lab to be made up on unicellular, colonial, and filamentous blue-green algae, mostly belonging to the Oscillatoriaceae; with these is a great variety of diatoms, bacteria, unicellular green algae, protoza, rotifers, minute or microscopic worms, and crustacea, and a small proportion of very fine filamentous green algae, such as *Cladophora*, *Spirogyra*, and *Chaetomorpha*.

The nursery pond is first drained, cleaned, and allowed to dry for two weeks or more. This is the time to get rid of all enemies of bañgos fry. When the pond is thoroughly dry, water is let in to a depth of 10 centimetres. After three or four days lab-lab begins to grow on the bottom of the pond and soon forms a dense mat over the whole floor. As the lab-lab develops the water is gradually increased until it is about 25 centimetres deep. The water in the nursery pond must be kept clean and fresh by changing it at every tide, or at least once a day.

The nursery pond must be in complete readiness when the fry are obtained, and great care must be taken that conditions are just right and are kept so. The first three or four days in the pond are the most critical. Great care is necessary to avoid overstocking the nursery pond. A hectare of nursery pond with a fine growth of lab-lab can support 300,000 bañgos fry 10 to 12 mm. in length, but the kawag-kawag are usually kept in pabiayan, a small subdivision not more than 40 metres by 40 metres. In two or three weeks they should be 30 to 35 mm. in length, and are then ready to be removed to another enclosure or bansutan, which should not have more than half as many fry in the same area. If conditions are at all favourable in the nursery pond the fry should be 40 to 50 mm. in length in four to six weeks, and ready to transfer to the larger or stock ponds.

One of the most marked characteristics of bañgos is their trait of swimming against a current. This makes it easy to catch them when very young and delicate, and to transfer them from one pond to another at all ages. When water is admitted through the sluice gate, bañgos, from the smallest to the largest, crowd together to meet the inflowing current. This makes it very easy to catch them in dip nets and to move them about without lifting the net from the water or taking the fish out of water.

Fry from 35 to 50 mm. in length are called hatiran. A hectare of pond in first class condition will keep 10,000 hatiran for a short time, until the stock pond is ready. Hatiran usually remain from two to three months in their special pond, and are then 75 to 100 mm. in length. They are then called garongin.

Many people put altogether too many garongin in the stock pond. It is possible for some ponds in fine condition, with all circumstances most favourable, to carry 1,500 to 2,000 hatiran or garongin per hectare. At the same time most ponds with a luxuriant growth of lumut give better results if not more than 800 to 1,000 fish per hectare be placed in it. Then if experience demonstrates that more may be carried with safety, additional fish can be added gradually until the limit is reached. Many people lose heavily or even fail because they overstock their ponds.

Before placing fish in the large or stock pond it should be drained and allowed to dry for three days to a week, according to the weather. All snakes, predaceous fish, crabs, and other enemies should be destroyed. When the pond is ready, water should be run in to a depth of about 10 centimetres. This will start the lumut or algae to growing in small rounded clumps all over the bottom of the pond. As the lumut grows the depth of the water is gradually increased. The young fish feed on the lumut, but if there is the correct ratio of fish to the crop of algae there will be plenty of feed. Under very favourable conditions the growth of algae may be so luxuriant that some must be removed so that the fish may have room to move about freely. On the other hand, prolonged heavy rains or the irruption of flood waters may reduce the salinity of the ponds and seriously check the algal growth. Flooding by fresh water also promotes the growth of grass in ponds, and may seriously reduce the quantity of lumut available. Every effort should be made to prevent the entrance of fresh water into bañgos ponds and the reduction of their salinity. With flooding by fresh water, dalag (*Ophicephalus striatus*), and climbing perch (*Anabas testudineus*), are sure to enter. The presence of either causes much loss, but the presence of both is a calamity to the fish pond owner. Restoring the proper salinity of the water is the most effective way of eliminating both of these pests.

Garongin 10 centimetres long should reach marketable size in two or three months after being placed in a large pond where all conditions are favourable. There is no fixed time for stocking the large ponds. Whenever the pond is in the right condition and one can get strong healthy hatiran or garongin is the time to plant. The dry season is really the best planting time, as weather conditions are more favourable and it is easier to keep down enemies.

Harvest time in bañgos ponds varies greatly according to locality and the ideas of the management. There are two general plans; one is to have two crops of bañgos a year, the other to produce but one crop a year. Each method has its advantages, but usually harvesting the bañgos twice a year is the more profitable method where marketing conditions are at all favourable. The smaller fish obtained by the method of growing two crops a year are much more saleable than the much larger fish harvested under the one crop a year system. The common people, with their low purchasing power, are the chief buyers of bañgos. They will buy two or three small bañgos more readily than one of a larger size which costs as much as the three.

When conditions are favourable bañgos make a remarkably rapid growth, attaining a weight of 300 to 500 grams under the plan of harvesting them twice a year. It is estimated that Philippine bañgos ponds produce almost 70,000,000 pounds of fish annually, with a market value of approximately 30,000,000 pesos, or 15,000,000 dollars. Besides the sale of bañgos, many pond owners derive an appreciable revenue from the sale of mullet, shrimp, eels, and other fish in the ponds, and from the sale of firewood from mangrove trees, and leaves of the nipa palm for roofing.

The Philippine Bureau of Fisheries says average ponds produce about 310 pounds of fish per annum, rearing one crop a year, while good ponds produce as much as 660 pounds. Raising two crops a year would give an average crop of over 600 pounds annually, while first class ponds turn out over 1,300 pounds in the same time.

A great many factors are involved in determining the rate of growth of bañgos in ponds. Among the more important are the following:—(1) The rate at which the pond water is renewed by replacing stale water with clear fresh water of the right salinity. (2) Water circulation within the pond system. (3) Amount of rainfall. (4) Sudden changes in salinity. (5) The kind of soil composing the bottom of the pond. (6) The kind, amount, and quality of food available for the fish. (7) The size and depth of the stock ponds. (8) The number of fish per hectare. (9) The number of bubuntis (*Mollienesia latipinna*) or other fish living on the same kind of food as bañgos.

There are still enormous areas of nipa and mangrove swamps in the Philippines, as well as in many other tropical regions in the eastern hemisphere. Not all such swamps are suitable for fish ponds, but the majority are. With the rapid increase in population, and consequently a much greater demand for food, there should follow an expansion of the bañgos fish pond industry. Especially should this be true of those regions where there is at present little or no development of bañgos culture, but which have a considerable population and therefore a ready market. Bañgos culture offers a means for utilizing waste land or land of little value, and increasing the available food supply at the same time. Both these objectives may be attained without infringing upon or interfering with any industries or business already established.

A great many factors concerned in the successful management of a bañgos pond cannot be learned from the printed page, no matter how elaborate the instructions. Such things as the proper control of the flow of water, its intake, outgo, and movement from one compartment to another, the preparation of the nursery pond, the growth of lab-lab, the proper care of the very young fry, the proper growth of the filamentous algae or lumut, even the construction of dikes, are best learned by observing the methods of the most successful growers, then checking them with the director of the experiment station and the manager of the great ponds of the National Food Corporation.

No study of fish ponds in the United States, Europe, or any temperate country can possibly prepare one for the successful operation of a bañgos pond in the Philippines or Java. The attempts of the United States authorities who brought a fish pond "expert" to Manila to teach the Filipinos how to grow bañgos, have been both pathetic and ridiculous, as well as a great waste of time, effort, and money.

The present methods have been evolved by rule of thumb and embrace the results attained by countless experimenters who have won to the present standards by the age-old way of trial and error. Mingled with a great deal that is sound and cannot be set aside, are practices based upon faulty deductions from the observed phenomena, as well as superstitious beliefs that have arisen and become part of the traditional lore of bañgos culture.

Some years ago the Philippine Bureau of Fisheries established an experimental station for the study of bañgos culture at Dagat-Dagatan, a few miles north of Manila between the two fishing towns of Navotas and Malabon. Besides carrying on a great deal of work on pond methods, fundamental work on the kawag-kawag or very young fry and on lab-lab and its components, was carried on for several years. Miss Louise Victoria Smith studied the fundamental problems, such as the organisms making up lab-lab, their physiology and development, the most favourable factors affecting the growth of the fry, and numerous other problems. Miss Smith conducted her experiments and observations for five years, and had submitted four papers for publication when the Japanese struck. All the results of her studies were lost, as well as all the conclusions attained by H. R. Montalban, who was in charge of the station and had been working on pond problems for nearly ten years. The Japanese army in the Philippines took a malicious delight in destroying everything of a scientific or educational nature. At present the station is merely marking time until it is rehabilitated. It is hoped that the plans for bringing Miss Smith back to the Philippines to resume her valuable work may materialize soon. No effort should be spared to place bañgos culture on a scientific basis as soon as possible.

The culture of bañgos or bandeng has been carried on in Java for many centuries, probably hundreds of years before it was begun about Manila Bay. The Javanese construction of ponds and gates is not as good as the Manila Bay standards, and the methods of cultivation in Java are apparently less effective than those in the Philippines. However the ponds of Java and Madura produce large amounts of food and fill an important place in the local economy.

It is believed that the cultivation of bañgos could be much extended where it is already practised, with more attention paid to following the best practices, as exemplified in the Malabon area. Pond and gate construction, and a better understanding of the problems connected with the growth of algae and handling of fry, are among the lines which most need improvement in many localities.

Little or no cultivation of bañgos is attempted in Indo-China, Siam, the Malay Peninsula, and India. In each of the countries named there are plenty of localities favourable for the culture of bañgos fry and the rearing of bañgos for the market. The industry should be of great public benefit in all the countries named. There is likewise no bañgos culture in the Outer Islands of the East Indies, from Borneo to New Guinea, though the conditions are favourable in many regions and there are good markets in many places.

Bañgos occur from the Red Sea and east coast of Africa to the coast of Central America and the Gulf of California, and from southern Japan to New Zealand. This means that some day our descendants may see bañgos cultivated over much of this vast area, with great benefit to the people inhabiting a large part of the Indo-Pacific island world, as well as the lowlands of the south and south-east of Asia.

THE POND CULTURE OF MULLET IN THE NEW TERRITORY, HONG KONG, CHINA

By Albert W. C. T. Herre, School of Fisheries, University of Washington, Seattle

In many parts of the world people have talked about rearing mullet, and have toyed with the idea of cultivating mullet in saltwater ponds, much as *Chanos chanos* fry are reared in the Philippines. Kelly began the experimental pond culture of mullet on the island of Oahu, Hawaiian Islands, but the work never progressed very far. The last time I visited the locality I found the ponds had been filled in, all work abandoned, and real estate promoters had taken over. I am not aware of any successful work along this line at any experimental station.

It was therefore a pleasure to visit ponds for the culture of mullet, under the competent guidance of my enthusiastic friend, Mr. Lin Shu-yen, of the Hong Kong Fisheries office. The ponds are near the village of Un Long, in the New Territory, about 30 miles from Kowloon, which is across the half-mile-wide channel from Hong Kong.

When I visited the ponds some had been in operation almost twelve years. Experiments were still being carried on, but enough had been learned about the principles of mullet culture to make the business a very successful one. The ponds occupy a considerable part of a tidal flat, and rain is their only source of water supply. This is unfortunate, since the lack of a permanent stream or other dependable supply of fresh water is a grave disadvantage in maintaining the ponds at a satisfactory water level. The most difficult problem in connection with keeping both mullet and carp in the same ponds is that of having an adequate supply of water at all times.

In making a pond the area is first enclosed by a high, wide, strong dike. The earth for the dikes is obtained from the areas to be converted into ponds. Unlike bañgos ponds, the ponds here are excavated to a considerable depth, so that they have from four to eight feet of water, or more in some cases. After the ponds are made they cannot be used for a year or more, as their soil is too salt. Rain water dissolves the salts on the bottom, and the ponds are drained as far as possible, a number of times. During the rainy season temporary rills and brooks may bring water from the nearby hills, thus augmenting the water supply materially. In spite of all that can be done it is not possible to get ponds with pure fresh water. There is always a slight salinity or brackishness, but every effort is made to get the water as nearly fresh as possible. This is done so that various carps may be cultivated with the mullet.

In order to have a successful pond, it is necessary to fertilize the water heavily. This is necessary so that the growth of plankton and algae may be rich and vigorous. The best fertilizer is cow manure, but other fertilizers are extensively used. Sheds have been built along the tops of the dikes between ponds. In these sheds pigs and chickens are reared for the Hong Kong market. Everything is kept scrupulously clean, all waste and excrement being washed into the ponds. The manager's house and the huts for the labourers are also built on the dikes, and partly overhang the adjacent ponds; all waste, especially that of the privies, goes into the ponds. When the water becomes light brownish-green in colour the fish farmers are satisfied. Its tinge is due to the organic matter in suspension, as well as clouds of minute crustacea and other forms of plankton.

There are seven or eight species of mullet in the Hong Kong area, with five rather common kinds. Of all these experiment has demonstrated that but one grows rapidly enough to be profitable in pond culture, and it is therefore the only one used. The one used is the common grey striped mullet, of almost world-wide distribution, *Mugil cephalus* L. It is very difficult to distinguish the fry of a number of kinds of mullet, but fortunately the fry of *Mugil cephalus* are readily separated from those of any other mullet.

The fry are caught locally at the mouths of brackish and freshwater streams and inlets. Experiment has demonstrated that the most suitable size for pond culture is from an inch to an inch and three-fourths in length.

In addition to planting mullet fry, the method of trial and error has shown that the young of the following different kinds of carp may be placed in the same ponds, with profit: the common carp, *Cyprinus carpio* L.; the grass carp, *Ctenopharyngodon idellus* (Cuv. and Val); the big-head carp, *Aristichthys nobilis* (Richardson); silver carp, *Hypophthalmichthys molotrix* (Cuv. and Val.).

Some fish farmers also add mud carp, *Cirrhina molitorella* (Cuv. and Val.), and *Parabramis pekinensis* (Basilewsky). In spite of all precautions taken by the fish farmers, some sea bass, *Lates calcarifer*, and sea-bream, *Sparus berda*, succeed in entering the ponds through the sluice gates. The sea-bass are desirable food fish, commanding a very high price, but are a loss to the fish pond owner, as they devour vast numbers of the other fishes.

When the ponds are stocked the number of mullet fry planted far outnumbers the other kinds. The most successful farmers plant about 1,500 mullet fry per mow, a mow being one-fifth of an acre. Along with that number of mullet fry are planted 50 to 60 grass carp, 400 common carp, and 100 big-head and silver carp.

Since the mullet and the various kinds of carp used in stocking the ponds all have different feeding habits, and none of them are carnivorous, they are non-competitive. If the ration is correct, the full capacity of the pond is utilized and the business of fish farming is on a much broader and more secure base with a consequent greater expectancy of profit for the fish pond owner.

To avoid overcrowding, the farmer begins to remove mullet as soon as the market will accept them, which is when they are a little more than five inches long. The various kinds of carp are hardier than the mullet, and do not need to be thinned as they can stand crowding much better. By removing saleable mullet, those that are left have more room, so that they grow faster, and likewise have a better oxygen supply. If they are overcrowded mullet often die of suffocation. By the time mullet are a year old they should weigh over a pound. When they are two years old they should weigh two and a half pounds or more, and bring a very high price.

All fish caught are taken with casting nets. Owing to the peculiar conditions under which the ponds are maintained, this is probably the best method of taking them. By the time the fry have been in a pond for four months some are taken almost every day. By taking only those above a certain size, more room is left for the others and they grow faster. No more fish are taken than the market will absorb readily. All fish taken that are smaller than the size set by the manager are released from the net without being removed from the water. In this way they have no scales loosed, and are not harmed, so that they continue to grow.

All carp caught are kept alive for the market, in tubs or live boxes, as they stand confinement very well and will endure long journeys without harm. It is very difficult to keep mullet alive under the same conditions, so they are left dead in the sampan. Those that are sent to the Hong Kong market are iced to keep them fresh, but that is not necessary for those that are sold locally.

The natural food developed in the pond includes a great quantity and variety of life. Plankton, green algae, *Lemna* or duckweed, crustacea, insects and their larvae, worms, snails, tadpoles, and organic detritus are all there, but it is not enough to properly nourish the fish in a well stocked pond. It is therefore necessary to supply additional food. All kinds of grass, vegetables, weeds, and tree leaves are thrown into the ponds. Rice bran, peanut cake, and soybean cake are also used. Mullet are particularly fond of rice bran. Several bags of bran are scattered about at the edge or in shallow water, one end of a bag left open so that the mullet can get at the contents. Large quantities of cooked and dried silkworm pupae are also used, particularly to feed grass carp.

The writer believes that mullet culture could become a profitable industry in other regions. It would be necessary to carry on a good deal of experimentation in order to determine what species could be cultivated in a given region. For instance, the Ganges Delta and the

Manila Bay area are both rich in species of mullet, but *Mugil cephalus* does not occur in either locality. It would therefore be necessary to determine whether some other species could be grown in ponds with profit.

THE PHILIPPINE FISHERY PROGRAMME

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Authority

The Philippine Fishery Programme conducted by the United States Fish and Wildlife Service in co-operation with the Bureau of Fisheries of the Republic of the Philippines was authorized by the United States Congress through the Philippine Rehabilitation Act of 1946 (Public Law 370 – 79th Congress, approved April 30, 1946). Pursuant to such authorization a co-operative agreement covering arrangements for conduct of fishery rehabilitation and development work was executed by the Governments of the two countries on March 14, 1947.

Personnel and Equipment

Before rehabilitation work could start it was necessary to create an organization for that purpose and procure the necessary fishing vessels, fishing gear, scientific equipment, laboratory supplies, office equipment and many miscellaneous supply and material items. The ravages of war had stripped the Philippines bare and it was necessary that all needed equipment, supplies and materials be obtained in the United States and shipped to the Islands. As a result fishery rehabilitation work within the Philippines did not get under way until the summer of 1947.

Key administrative, marine and scientific employees, including biologists, ichthyologists, chemists, bacteriologists, technologists, and economists were recruited in the United States and brought to the Philippines for work on this programme. The number of employees engaged on programme work on November 30, 1948, was as follows:

Unit of Organization	*Americans*	*Filipinos*	*Total*
Administration	7	10	17
Biology and Oceanography	4	40[2]	44
Technology	5	10	15
Economics	1	1	2
Maintenance and Miscellaneous Service	1[1]	18	19
Vessels' Crews:			
Spencer F. Baird	12	13	25
Theodore N. Gill	4	12	16
David S. Jordan	—	7	7
Total	34	111	145

[1] Includes 1 employee of Australian citizenship.

[2] Includes 15 temporary labourers and skilled tradesmen engaged in rehabilitation of the Dagat-dagatan Experimental Fishery Station.

Two war-service vessels, more fully described below, were acquired by bare-boat charter from the United States Maritime Commission. Conversion and outfitting necesary to adapt them to fishery work was done in the United States; conversion having been performed at yards within the vicinity of San Francisco, California. These two vessels arrived in Manila Harbour on August 17, 1947. An office and laboratory are located in a large two-story quonset building erected on the grounds of the American Embassy in Manila. The laboratory contains complete facilities for oceanographic, biological and technological work as more fully described later in this paper.

The SPENCER F. BAIRD is the former U.S. Army LT-581 which has been converted into a combination oceanographic vessel and tuna clipper. It is 143 feet long, with 43 feet beam and a draft of 16 feet. Propulsion power consists of twin diesel electric installations geared into a single shaft and propeller which provide flexible speeds of operation ranging from 1½ to 14 knots. The vessel is equipped with a gyro-compass, range finder and a 4,000-fathom-type recording fathometer. A biological and chemical laboratory is installed on the main deck, as well as special winches for handling hydrographic gear, and experimental trawls and other types of nets. A sharp-freeze compartment for experimentation with freezing fish at sea is located in the after hold. On the after deck, live bait tanks have been installed which are equipped with refrigeration and aeration that make possible experimentation in the handling of bait under all types of conditions. Fishing racks have been installed aft, around the stern of the boat, which can be used for tuna fishing with poles, as carried on in the Southern California tuna fishery.

The THEODORE N. GILL is the former U.S. Navy minesweeper, AMC90. It is an experimental purse seiner and "west coast" type trawler. It is 97 feet long, has a 23-foot beam and a draft of 11 feet. Power is supplied by a six-cylinder diesel engine with reduction and reversing gear which provides for a cruising speed of about 10 knots. Like the *Baird*, but on a somewhat reduced scale, it is equipped for oceanographic work and has a small biological and oceanographic laboratory. A turntable on the stern is provided for the operation of purse seines like those now in commercial use in the sardine and tuna industries. Trawling gear is of the type used on the western coast of the United States. A winch, boom and other necessary installations for this type of gear have been provided.

The DAVID STARR JORDAN was designed, built and always used as a commercial fishing vessel. It was purchased from its private owner by the Fish and Wildlife Service in July, 1948, and shipped to Manila. The vessel is of 30 gross tons, is 48 feet long, has a beam of 13 feet, and a draft of 6 feet. It is powered by a 135-h.p. diesel engine and has an 8-h.p. engine for bait-tank pumps. Other equipment and installations include engine-room controls in the pilot house and on the flying bridge, a 250-fathom range fathometer, direction finder, radio-telephone, Rowe drag winches with port and starboard mounted drums each with a capacity of 300 fathoms of ½-inch cable, and an anchor winch with a capacity of 125 fathoms of ⅝-inch cable and 15 fathoms of anchor chain.

THE BIOLOGICAL AND OCEANOGRAPHIC PROGRAMME

The biological and oceanographic aspects of the Philippine Fishery Programme have two primary aims. One is to ascertain the limits of the fishing grounds and gain an idea of their productivity, both in kind and quantity, and the other is to understand the basis upon which productivity, if any, flourishes. The first aim is considered to be a biological problem and is further subdivided into two types of endeavour, viz., exploratory and natural history studies. The second aim also assumed two aspects in the original thinking which may be defined as hydrodynamics and trophodynamics. The biological effort may be further subdivided into the investigation of pelagic species and demersal species.

In addition to these broad, basic subdivisions of the general approach to the work of the project many problems of a more specific nature had to be considered, the most important of which was methods of capture suitable for the localities and species of the region. In addition, problems arising from the current exploitation of certain grounds are being worked on in conjunction with the Philippine Bureau of Fisheries.

The report that follows deals with the progress which has been made toward the primary biological aims of the programme. Specific reports now in the process of being prepared for publication or data now being evaluated will be indicated. The oceanographic aspects which are considered to be basic to all biological problems will be reported elsewhere at this meeting.

An effort has been made to integrate the work of the scientific personnel and the two vessels, *Baird* and *Gill*, so as to take full advantage of the facilities and time available. Thus oceanography, natural history, and exploration were combined in the efforts of the *Baird* on most voyages and two or sometimes three types of fishing endeavour were attempted on many trips of the *Gill*. Extension work and academic work, incidental to the main problems at hand are described under a miscellaneous heading.

Exploratory Efforts of the Theodore N. Gill

Approximately 50 per cent of the effort of the *Gill* during the 1947-48 year was spent in an effort to explore the possibilities of the demersal fishing grounds of the central Philippines. When the programme was initiated a small fleet of "draggers" was already operating on grounds of easy access to the Manila market, mostly Manila Bay, using the Japanese modification of the beam trawl, the "utase". This type of effort had been introduced in the Philippines by the Japanese years previously and was carried on through the period of the occupation to a limited extent. Following the liberation of the islands from the Japanese a few of these vessels were salvaged and other craft were improvised for this purpose. In addition to the utase one operator was trying out an otter trawl on the basis of information supplied by an earlier reconnaissance team sent to the islands by the Fish and Wildlife Service.

The purpose of the exploratory work was three-fold. It was first hoped to find new grounds, since the areas being worked were being rapidly depleted, next it was hoped to extend the known grounds, and finally it was hoped to supplant the utase with the more efficient otter trawl.

Trawling in Manila Bay is confined to shallow water, mostly in depths ranging from 3 to 30 fathoms. This seems, in part, to be due to limitations of the gear and in part, to the unfamiliarity of local fishermen with other grounds. So the first effort made was to explore the possibilities of fishing in deeper water. On the whole this attempt was unsuccessful. There was first encountered the debris from the war that practically blanketed the most promising areas. Secondly, the productivity of the grounds that were clear enough for fishing was low in terms of weight per unit of area, and finally the fish taken were mostly undesirable species. Altogether 23 hours of fishing effort were spent in making 27 drags that produced a total of only 966 pounds of marketable fish or aproximately 42·0 pounds per hour of effort. (See Table I, Trips 1, 2, 3 and 15.)

Subsequent efforts involved exploration in the waters adjacent to Panay Islands in the Visayan group (Trips 10, 13, and 14), Sibugey Bay, Mindanao Island (Trip 11), San Miguel Bay and other areas off east-central and south-eastern Luzon (Trip 12), and Tayabas Bay and Ragay Gulf on south-western Luzon (Trip 16). The total effort through Trip 16 is summarized in Table II.

From the data in both tables two facts are noteworthy. In comparison with other areas of the world where trawling is carried on, production in the waters of the Philippines is relatively low. On the basis of the gear used and the speed of the vessel (a 120-foot net of 4-inch mesh body and a 2-inch mesh bag fishing 50 per cent of the total width at a rate of two British miles per hour) production of marketable fish for all areas tested is in the neighbourhood of 11·5 pounds per acre. The best fishing grounds per unit of area are found in the Visayan Islands and off south-eastern and east-central Luzon where an acre off Panay produces 23 pounds and off eastern Luzon will supply 16·5 pounds. Production on the proven grounds in the Visayas is remarkably uniform while data not available here shows considerable variation on the grounds off eastern Luzon.

Such grounds may not seem worthwhile to work when compared with other areas in the world that have supported similar fisheries for many years. In the Philippines, however, they are very profitable at the present time inasmuch as prices, since World War II, are very high. Nor does the rapidly growing population of the nation presage a reduction in general price trends. Since grounds of such low productivity are relatively easy to exhaust it will be necessary to institute careful management plans if they are to continue to be of value to the nation in the future.

TABLE I.—EXPLORATORY OTTER TRAWLING OF THE *GILL*
TRIPS 1 - 16

Trip No.	*Locality*	*Total No. of Drags*	*Total Fishing Hours*		*Total lb. of Marketable Fish*	*Average Catch per 1-Hour Drag*
			hrs.	min.		
1	Manila Bay Approach	7	7	30	321	42·8
2	Off Bataan Peninsula	5	3	51	88	22·85
3	Manila Bay Approach	3	2	10	231	106·94
4	Manila Bay	2	2		37	18·5
5	Manila Bay	2	2		30	15·0
6	Manila Bay	2	1	35	130	82·27
7	Manila Bay	2	2		205	102·5
8	Manila Bay	2	2		89·5	44·75
9	Manila Bay	1	1		196	196·0
10	Guimaras St., Panay	9	9		3088	343·11
11	Sibuguey Bay, Mind.	4	4	24	9	2·04
12	San Miguel Bay and adjacent areas	22	19	20	4556·04	235·69
13	Panay Gulf and adjacent areas	15	14	35	4768·75	327·07
14	Northern Panay	4	4		1308·0	327·0
15	Manila Bay Approach and Bataan	12	9	28	326·0	34·45
16	South-western Luzon	15	12	33	653	52·0

TABLE II.—SUMMARY OF OTTER TRAWL EXPLORATIONS OF *THEODORE N. GILL*

Total No. of Trips	16
Total No. of Drags	107
Total Fishing Hours	97 hrs. 23 mins.
Total lbs. of Marketable Fish	164·67
Average lbs. per hour fishing	16,036·29

Demonstration Efforts of Theodore N. Gill

It was realized in early stages of the programme that a considerable amount of rehabilitation work could be accomplished by the Philippine citizens themselves provided that they had the proper inspiration and guidance. Consequently efforts were made to respond wherever possible to requests for technical guidance and assistance and efforts were also made to encourage expansion of existing fisheries by demonstration and instruction. Demonstrations were conducted in Luzon, Negros and Panay, and 56 prospective fishing-vessel operators, as well as those currently engaged in the business, were shown the otter trawl and its operation on voyages especially planned for the purpose. In addition, contacts in the Visayan Islands to encourage the development of the fishing fleet has led to an expansion in that area from approximately seven to almost fifty powered draggers.

The demonstration and educational work has not only caused additions to be made to the Philippine fleet but has also produced a degree of modernization. The chief objections to the utase as compared with the otter trawl lay first in the fact that the gear is, as used in the Philippines, very limited in the depths that can be fished, the ground that can be covered per effort, and the number of times it can be set and lifted in a working day while, at the same time, it requires more manpower to handle it. In all likelihood many improvements could be effected in the current practices in the use of the utase but since most of the objections could be overcome by the use of the otter trawl it seemed more advisable to urge the use of the latter rather than experiment with trying to improve the former. The results of a year of work along this line are shown in Table III. The results as shown, however, are not complete since the gear is being widely copied and only a casual effort is being made to keep abreast of the situation.

TABLE III.—SHOWING OTTER TRAWLERS ESTABLISHED AND IN PROGRESS THROUGH THE DEMONSTRATION WORK OF THIS OFFICE FROM 1947 - 1948

Place	*Year*	*Number Established*	*Number in Progress*
Manila	1947	3	0
Manila	1948	15	5
Iloilo	1948	3	0
Iligan	1948	1	0
Legaspi	1948	1	0
TOTAL		22	5

Manila Bay Studies

Among the problems brought to the attention of the Philippine Fishery Programme soon after its advent in the Philippines was the condition of the Manila Bay trawl fishery. The area had been very heavily exploited following the liberation from the Japanese. At the time the study began in the autumn of 1947, estimates made from the results of commercial fishing operations indicated that the fishable portions of the Bay were yielding approximately 3·6 pounds of fish per acre. This was so low that practically all the vessels then working were operating at a loss and vessels were being laid up or moved to other areas. The aims of the study were to assay this production and to determine if any segment of the population of any given species of fish was being exploited to the detriment of the species as a whole. It was further planned to determine which areas could support a fishery and which should be closed if necessary.

The Bay was arbitrarily divided into sub-divisions and a programme of dragging was arranged for the *Gill* and one of the vessels of the Philippine Institute of Fisheries Technology. The *Gill* was able to carry out her assignment with the following results:

1. One area, IV, was shown to be more productive than others.
2. A definite relationship was found to exist between abundance of the species in various families and the depth of capture.
3. A definite relationship was shown to exist between the average size of a species and the depth of water where captured.
4. In shallow water most of the fish taken were sexually immature.
5. In deeper water most of the fish taken were sexually mature.
6. The approximate minimum size attained at sexual maturity, based on gonad examination, was determined for the females of thirteen species of common Manila Bay fishes.
7. Very few marketable food fishes were caught at depths greater than 40 fathoms.
8. The predominant species in the deeper water were fishes with hard exoskeletons and non-marketable.

A typical catch of a drag-net such as an otter trawl or beam trawl in the Philippines will produce species divided among at least 25 families. While some species are more plentiful than others the commercial catch is always mixed. Thus in the Philippines there is nothing comparable to the "cod fishery" or "plaice fishery", for example. The most striking thing about the catch composition of the Philippine dragger fishery is the wide variety of species that composes it. Often a drag or two will produce 60 distinct kinds of fishes. The lack of predominance of a species upon which the market for dragger-caught fish can be based, and around which scientific interest can be centred, renders management procedure a difficult and complicated problem. This factor will ultimately demand a fresh approach and rigorous enforcement. Just what form this will take it is impossible to predict at this time.

These data suggest that consideration be given the idea of closing certain areas to trawling and limiting the size of the mesh in the nets. Further thought will have to be given this problem, however, since it is fundamentally concerned with a dual fishery. Judging from casual observations made at the principal fish landing, approximately 40 per cent of the value of the catch is derived from shrimp and 60 per cent from fish. To limit the grounds to protect growing fish and the size of the mesh for the same purpose will seriously curtail the supply of shrimp, which are a staple item on the market. As time allows additional effort will be put on this problem to ascertain the advisability of (a) closing the Bay completely for a period of years, (b) imposing a season of operations, or (c) arranging a rotational plan for the more productive localities within the Bay.

Exploration for Sharks for Vitamin Oil

Of all the potential values in the Philippine fishery resources, none has been of greater interest to foreign interests than the possibilities of obtaining shark liver oil for vitamin oil production. Since a vitamin industry would be a valuable asset to the nation, a programme of exploration for sharks was begun. In determining the course of this work further consideration was given the fact that, even if exported, no readily marketable item was being removed from the national food list and that sharks are an unexploited resource in the Philippines at present.

The *Gill* was equipped with long-line trawl gear and efforts were made to take sharks coincidentally with other types of fishing. One prolonged voyage to the Sulu Archipelago was conducted specifically for this purpose. Localities of the voyages of the *Gill* are identical with those for otter trawling shown in Table I, Trips 11 through 15.

The results for five voyages are shown in Table IV. One cruise is not reported since at this writing the data are not yet compiled. At the same time one cruise of the *Baird* made in December, 1948, was devoted to shark long-line trawling and those results are also not included at this time. A full report of the effort of both vessels is being prepared for publication.

The preliminary summary of results of the effort of the *Gill* is shown in Table V. The work is reported in "efforts" and "sets". The "effort" may be defined as all of the gear available being fished for whatever time was available. The set of 600 hook hours is the standard "unit of effort" used by the project to indicate the abundance as demonstrated by the type of gear in question. The factors within the unit called a "set" are 50 hooks fishing for 12 hours. A set extends for approximately one mile in the sea. The daily average production for a vessel fishing one mile of long-line for all Philippine waters explored by the *Gill* is approximately one shark weighing 314 pounds and having a liver weighing 70 pounds. The most productive grounds were encountered on trips 11 and 14. These were off Mindanao and the Sulu Archipelago and northern Panay Island. The poorest production was encountered in Panay Gulf on trip 13. It is only just to state that trips 12 and 13 hardly constitute a fair sample since not enough effort was expended in either area to compile comparable data. Weather and other conditions limited the time allowable to the effort on both occasions but since production in other areas shows no greater promise than it does it is doubtful if further work will be done in these areas on this problem.

TABLE V.—PRELIMINARY SUMMARY OF SHARK FISHING EFFORT OF THE *GILL*

	Totals		*Averages*
No. of efforts made	55	Catch per set	1·02
No. of hooks used	3,987	Lbs. of shark per set	313·63
No. of sets	102·13	Lbs. of liver per set	70·3
No. of fishing hours	862 hrs. 57 min.		
No. of sharks caught	105		
No. of lbs. liver	7,180·42		
No. of lbs. of shark	32,031·5		

TABLE IV.—RESULTS OF EXPLORATORY SHARK FISHING OF THE *GILL*

Trip Number	*11*	*12*	*13*	*14*	*15*
No. of efforts made . .	23	1	4	9	18
No. of hooks used . .	2,241	100	297	458	887
No. of fishing hours . .	351 hrs. 24 min.	14 hrs. 30 min.	55 hrs. 25 min.	129 hrs. 58 min.	311 hrs. 40 min.
[1]No. of "Sets" made . .	57·06	2·41	6·85	10·22	25·29
No. of sharks caught . .	59	2	4	15	25
No. of sharks per set . .	1·03	0·82	0·58	1·46	0·97
Total lbs. of shark . .	19,064	1,385	910	3,641	7,031·5
Total lbs. of liver .	5,544·72	337·5	182	659·2	1,457
Pounds of shark per set . .	334·1	574·68	132·84	356·26	589·12
Pounds of liver per set . .	72·12	140·04	26·57	64·5	89·45

[1] "Set" is equivalent to 50 hooks, fishing for 12 hours.

Natural History

During the operations of the *Gill* certain data of interest from the standpoint of natural history was accumulated. The study begun in Manila Bay had a problem of this nature as an objective when it was sought to determine the sexual maturity of certain segments of the catch. The results, in a general way, are reported in the section on exploration previously noted. Certain additional details are informative and bear upon the general problem involved in the rehabilitation of the Philippine fisheries.

During the course of explorations for shark, data was accumulated on the life history of the tiger shark *Galeocerdus arcticus,* and a paper on this subject is now in preparation. Both of the above will be made the subject of separate reports.

EXPLORATORY EFFORTS OF THE SPENCER F. BAIRD

The motor vessel *Baird* was used for a dual purpose during the operation of 1947-48. The primary objectives were the same but the nature of the work created two distinct types of endeavour. The primary aim was a study of pelagic fishes and for this purpose two types of endeavour were used. One was oceanography which was done in order that there should be available certain ecological data, and the other was a variety of activities by means of which it was hoped to ascertain the abundance of the tunas of the Philippines. To this end 14 voyages were made from September, 1947, through November, 1948.

In an effort to estimate the advisability of establishing a fishery for tuna several routine operations were evolved. First, a "fish watch" was set up and was manned on all daylight watches, trolling lines were fished when the vessel was under way during the day and efforts were made to take tunas by bait fishing. In addition night-lights were put over at every opportunity and fishes responding to them were collected. Plankton tows were made with the hope of finding larval scombroids.

Fish Watch

Fish watches were maintained by biologists as routine tasks. Fish-watch began at 0600 and ended at 1800 each day, or at such odd hours as the *Baird* was under way. The records of schools of fish seen in an area constitute a rough estimate of the actual fish present.

Five hundred and ninety-five schools of fish were seen during the first year of operation. Of these 51 were thought to be bait fish and 544 schools were presumably food fish. Definite conclusions concerning abundance cannot be formulated because only one year of operations has elapsed and not all areas have been covered. An average of 2·9 schools of fishes of both categories were recorded on each day of observation. Tabulation of fish-watch records indicates the presence of more visible schools of fish around Zamboanga area, Sulu Archipelago and the northern Moro Gulf. Fewer fish were seen the further north observations were made. In the localities in which the observations were made, two pronounced peaks of abundance appeared; one in December (4·8 schools per day) and one in May (8·2 schools per day). The lowest abundance was noted in the Celebes Sea in August.

Trolling

Nine trolling lines were operated from the deck and from outriggers on the *Baird* whenever the vessel was under way from daylight to dark. Since the start of operations the *Baird* trolled 1,950 actual hours, or 12,239·64 hook-hours (hooks in operation X hours trolled). Fish caught by trolling totalled 1,274 and weighed 7,889 pounds. Ten species were represented in the catch listed as follows: *Katsuwonus pelamis, Neothunnus macropterus, Euthynnus yaito, Elagates bipinnulatus, Katsuwonus tonggol, Auxis thazard, Scomberomorus commerson, Sphyraena picuda, Acanthocybium solandri, Coryphaena hippurus.* In addition to these species several varieties of carangids were encountered sporadically.

The effort produced 0·6 pounds of fish per hook-hour. Without reference to locality or species two peaks of abundance were noted. One in December and January produced 1·1 lbs. per hook-hour, and the other in April, May and June yielded 1·3 lbs. per hook-hour. Production by trolling ranged from 0·0 lbs. per hook-hour in October off northern Luzon and November off Zamboanga to 1·48 lbs. per hook-hour in June off the Zamboanga Peninsula.

All fish caught by trolling are examined. Length, weight, sex, gonad condition, stomach contents and other biological measurements are recorded. The results of the troll catch are being studied for areas and seasons of abundance, spawning activities, length-weight studies, and racial differentiation. It is interesting to note that in the tunas, *E. yaito*, *K. pelamis*, and *N. macropterus*, individuals in spawning condition have been taken throughout the year.

Bait Fishing

Bait fishing for tuna after the manner of the well-known southern California fleet was tried during the operations of the *Baird* but the results thus far have been disappointing. Several factors contribute to this lack of success but in general the behaviour of the fish in Philippine waters militates against this method and the problem of procuring bait has been extremely difficult.

The bait problem is not insurmountable but the methods used in the American fishery have not worked in the Philippines. The bait stations established by the Japanese are no longer in operation and to re-establish them is beyond the means of the Programme. As a substitute to sardines and anchovies ordinarily used on bait boats, milkfish or bañgos (*Chanos chanos*) fingerlings were carried in the tanks of the *Baird*. While there is some doubt as to the ultimate suitability of these fish as tuna attractors they are eminently satisfactory otherwise. They are very hardy, carry well in the tanks, and are easy to handle. Offsetting this, however, is the fact that in the Philippines they are very expensive. Bañgos were the only bait fish the *Baird* was able to obtain in quantity. Judging from reports of experience in the American fishery larger numbers will have to be secured in the future to assure adequate trials.

The scarcity of schools of fish that were suitable for fishing and the wariness of the fish in general were two important factors contributing to the lack of success of the bait fishing effort. Seldom were schools seen that had the appearance of being suitable for an attempt and most of the time it was impossible to approach a school sufficiently close to fish it. The apparent lack of suitable schools may, of course, be attributable to not being in the right place at the right time. Insufficient time and only one vessel has hampered the attempts to properly evaluate live-bait fishing. Experimental bait fishing should be the full-time occupation for a small fleet of suitable boats with well-trained crews, in addition to an extensive bait-station organization.

The *Baird* was able to fish with live-bait eleven and one-half hours fishing time. This fishing has been in the Sulu Sea and around the Sulu Archipelago. More suitable schools of fish were seen in that area than in any other place.

Night Light Stations

Night light stations were established at every opportunity during the past year. The purpose of these stations was threefold; first to determine the presence of bait-fish, since much fishing for similar forms is done with lights in the Philippines, second to find young scombroid fishes, and finally to evaluate the fish appearing around the night light in terms of what was found in the stomachs of the various pelagic fishes collected. The availability of bait fishes around the night lights has proved to be almost negative, they were seen in moderate numbers only a few times. A few of the young of various scombroid fishes were collected in the month of May. Some of these, however, are young tuna and may prove to be highly significant.

Twelve specimens of the frigate mackerel *Auxis thazard* were taken that ranged from 21·8 to 55·0 mm. standard length, seven specimens of *Auxis tapeimosoma* that were from 32·0 to 75·6 mm., 13 *Neothunnus macropterus*, 9·0 to 31·5 mm., five *Euthynnus yaito*, 29·5 to 102·0 mm. long, and six *Katsuwonus pelamis* that ranged from 11·5 to 25·5 mm. standard length.

The night light stations have proved to be interesting ichthyologically in that stray specimens of rare species are occasionally found. These records are being prepared for publication. One hundred and fourteen night light stations were made during the past year, with a total of 288 hours operation. Station locations ranged from the centres of the Sulu and Celebes Sea to small secluded bays and reefs. The collections from the past year are stored at the laboratory in Manila where they will be sorted and identified.

Plankton

During the course of a year of operation of the *Baird* a total of 158 plankton tows were made, mostly in the Sulu and Celebes Sea. The total time towed was 93 hours. This represents mostly one-half hour tows, although a few one-hour tows were made. There were 87 tows made between the hours of 0600 and 1800, and 71 tows between 1800 and 0600. In general night surface tows have been more productive than day tows. With the exception of a single experimental tow of 386 metres, all tows were made at the surface. Plankton quantities are not as abundant, judging from preliminary results, as in other places in the world where large fisheries are carried on. The collections of plankton made during the year have been preserved in formalin and returned to the laboratory in Manila where they are now being sorted and studied.

Natural History

The natural history of the species encountered on the *Baird* will be made the subject of a separate report which is to be presented at the forthcoming fishery meeting. This work will include the observations of the biologists on the items listed under the discussion of the trolling effort. This report will also include the observations of the biologists made in selected markets in Zamboanga, Batangas and Manila. In addition work has been done on several reports and three have been completed, one of which is now published. A check-list of Philippine fishes was prepared by Dr. Albert W. Herre during his tenure as a member of the Philippine Fishery Programme. A glossary of native and English common names together with the scientific names of the fishes of the Philippines was prepared and is now published. Various field keys to the major groups of commercial fishes are now in preparation and it is expected to have them ready for publication by the end of 1949. One entitled "Illustrated Key to the Important Families Found in Trawl Catches in the Philippines" by Herald and Umali is finished and in use on the programme.

A key to the Philippine fishing gear and discussions of its uses is in preparation. A manuscript on methods of reef fishing is soon to be released in bulletin form for the use of the fishing industry. This was prepared in an attempt to offer alternative methods for fishing these areas to the illegal dynamite that is now widely used.

Three reports under immediate consideration are concerned with the frigate mackerels of the genus *Auxis*, the juvenile stages of three species of tuna, and an analysis of the first year of trolling operations of the *Baird*. Other reports deal with problems of distribution and abundance as revealed by market-team studies, rare fish records and one on juvenile stages of tuna.

OCEANOGRAPHIC WORK

The stated objectives of the Philippine Fishery Programme are based upon the assumption that the ultimate aim of the Republic of the Philippines is to manage the fisheries resources of the nation for maximum sustained production. This, it is thought, cannot be achieved without a fairly comprehensive understanding of the nature of the resources, together with the bases for their production.

In other words it is postulated that the management of the fisheries of the Philippines (or any other for that matter) must be based upon a thorough understanding of the dynamics of the water containing the fishes. These processes take two forms (a) hydrodynamics, which will aid in the explanation of the transport of fundamental biological materials, and (b) trophic dynamics which seeks to explain phenomena involved in the utilization of those materials.

The oceanographic programme to date has consisted of surveys of the Sulu Sea and the Celebes Sea. Each of these areas has been investigated during the two monsoon seasons by the occupation of a carefully spaced grid of stations covering both seas. These seas are practically unknown from a scientific viewpoint. A total of eight cruises of the *Baird* were necessary to cover each of the two seas during each of the two monsoon periods and 187 stations were occupied.

At each oceanographic station serial observations were made from the surface to 800 or 2,000 metres at 16 different levels. At each level temperatures were observed and water samples collected for analyses. These analyses included the determination of salinity, dissolved oxygen, phosphate, silicate, hydrogen-ion, alkalinity, nitrite, and nitrate. About 24,000 determinations were conducted.

In the laboratory at Manila the various computations necessary for the reduction of the raw data are being made. This includes the corrections of the temperature readings and computations of thermometric depth, density, dynamic height and current vectors. Many of these computations are completed and graphs are being prepared showing the distribution of the various observed or computed conditions at standard levels throughout the waters investigated. The computations and graphical presentations for the first survey of the Celebes Sea and the first survey of the Sulu Sea taken during the north-east monsoon have progressed to the point where a preliminary interpretation of conditions can be made. These considerations are being made the subjects of separate reports one of which is to be delivered elsewhere at this meeting.

Pondfish Programme

The pondfish programme has had two forms since the inception of the work in the Philippines. Both approaches were manifestations of the same fundamental problem, viz., exploring the possibilities of increasing the production of pond-reared fish. The two forms were experiments on speeding the growth of fry and reducing fry mortality, and achieving an understanding of the dynamics of the ponds in which it was hoped to gain improvements in basic fertility.

The pond fish industry in the Philippines as is true of several south-east Asian countries, is one of considerable importance. The industry produces the bañgos or milkfish, *Chanos chanos*, and from all indications available at present it would seem that this is one type of endeavour that will be rapidly expanded in the future. Thus the aims of the programme have been directed at rendering operations as efficient as possible. Current production varies widely and there are places where it is recognized that considerable improvement can be effected.

Progress to date has revealed several interesting trends-features of both the habits of the fish and of the dynamics of the ponds but the work has not progressed to the point where a report can be presented. Since the effort involved in the analysis of the internal mechanics of production is a relatively new endeavour several basic problems had to be considered. Methods to determine the quantities of nutrient salts had to be checked since bañgos ponds are areas of low and variable salinity. In addition methods of sampling had to be developed both as to space and in time. Methods for the quantitative evaluation of food for bañgos are still under consideration but worthwhile beginnings on these problems have been made. Chemical sampling procedures are fairly well developed and the techniques, aside from nitrates have been checked. Work on the main objectives is beginning at this writing.

MISCELLANEOUS

At the request of the Sponge Institute, the central body of the sponge industry in the United States, efforts have been made to re-establish the sponge industry. This is meeting with success and at least two operators are planning work to begin after the receipt of the information concerning samples submitted to the Institute. The programme has been able to assist in the encouragement of the establishment of a netting industry and two mills are now scheduled to begin operations early in 1949.

The Philippine Fishery Programme has endeavoured to assist the Philippine Bureau of Fisheries in many of its outstanding problems, the most important of which is the prevalence of illegal dynamite fishing. This problem was brought to the attention of the programme when its representative first arrived in the Philippines, and attempts have been made to render all assistance within the power of the programme to ease this situation. It has assisted in designing and printing posters to be distributed throughout the islands for the inauguration of an educational campaign to discourage illegal wastage of the nation's fish. It has also assisted in the planning of a nation-wide Fish Conservation Day.

TECHNOLOGICAL STUDIES

The Technological Section of the Philippine Fishery Programme is concerned primarily with the following aspects of the fisheries in the Philippines: studies on handling and storing of fresh fish; processing studies, including those on smoking, freezing, canning, salting and drying; bacteriological studies; gear technological studies; and chemical, oil and reduction studies.

To facilitate this work a combined chemical and bacteriological laboratory, a pilot processing plant, and a net loft have been established in Manila. The chemical laboratory is equipped with a Beckman Quartz Spectro photometer for Vitamin A determinations and other special equipment necessary for analysis of oils and other fishery products. In the cannery there is a semi-automatic vacuum can sealer as well as smaller sealers of a portable type, canning retorts, a small smokehouse and freezers. The net loft has a tank equipped with heating coils for experimentation in gear tanning.

HANDLING AND STORAGE

Investigations on the handling and storing of fish have been carried out primarily in the Manila area because it has the largest market in the Philippines. A team of technologists has investigated these methods from the source of supply for that market, including the Bicol region, Batangas, Quezon Province and Bataan through the retail outlets. Observations have also been made aboard native fishing vessels primarily the beam trawlers operating in Manila Bay, and on the large bancas which fish in Batangas Province, south of Manila, to study the technique of catching and handling the fish aboard.

The usual method of packing fresh fish for land transport to the markets is to use an oblong wooden box lined with coarse leaf mats. The fish and ice are placed in layers within the box and over the top are placed banana leaves, another mat and a wooden top. Properly packed the ice will last 12-24 hours. Freshwater catfish and dalag are shipped alive in large cans or barrels of fresh water. On the beam trawlers the fishes are sorted aboard and put on flat rectangular trays holding about 4 kilos of fish. These trays are packed in the hold with a layer of ice on top of each of them.

Overland transport consists of open stake trucks, small quarter-ton trucks, buses and railroads. Air transport is used but the cost is high due to the difficulty of arranging two-way cargoes. No refrigeration trucks are used for the same reason. Practically all containers are returned to the point of origin for re-use.

The preferred and customary method of holding fresh fish for transportation to market either by boat or land transport is by icing but present ice costs are excessive. Under present laws, ice plants can be established only under government franchise.

One of the experiments being conducted by the Programme is the installation of a blast-refrigeration unit on the *Jordan*. The objectives of the experiment are to determine if the use of such a unit in combination with ice will, by prolonging the ice supply, reduce the cost of handling iced fishery products and extend the range of operations of the vessel.

The Filipino consumer is prejudiced against frozen fish and consequently the freezing industry has not expanded as rapidly as it has elsewhere. The most probable reasons for this prejudice are that it has been a practice to freeze questionable fish held over after a day's marketing activities and the fact that some of the fish frozen have been previously iced and improperly handled. Also, all the freezing facilities which have been surveyed thus far are not using sufficiently low temperatures to freeze rapidly and to hold the product at optimum storage temperatures.

So far there is but one vessel operating in the Philippines with proper equipment to handle frozen fish from the grounds to the market. This is a 135-foot wooden, diesel-powered vessel with a capacity of approximately 100 tons of frozen fish which carries high quality fish between the southern Sulu Archipelago and Manila. The Programme assisted the operator of this craft in methods of glazing and storing the catch and was able to demonstrate definite advantages in procedure which it is hoped will serve as an example to the industry.

Freezing experiments being conducted by the Programme are carried on at the pilot processing plants as well as aboard the Programme vessels. Current problems are concerned with studies to determine the length of time the various Philippine fishery products can be held in storage under several conditions of packaging and glazing.

PROCESSING

Several smoked products have been prepared among which smoked tuna "ham" and smoked oysters have attracted attention. Because of the interest in the latter product, mimeographed booklets on the manufacture of this item have been prepared and distributed.

Several species of fishes have been brine salted as well as dry salted and samples have been distributed to Filipino consumers for comments. From this was learned that heavily salted fishery products are not well received by the consumers because they are accustomed to the locally produced fish which is given only a light salt treatment and so can be cooked without the soaking required for a more heavily salted product. Brine salted fish would be a more satisfactory salted food to produce in the Philippines if by education people could be taught to use it. Submersion in brine would prevent mould-formation which is so prevalent on the salted product now produced.

It is generally agreed by other workers and is confirmed by experiments, that the salted fish products of the Philippines could be improved if a purer native salt could be manufactured. Consequently, studies are being made at a salt farm near Manila with a view to recommending improved methods of manufacture. One season's studies have been completed and further work is planned for the coming season. An article entitled "Philippine Solar Salt Industry" giving results obtained for the first salt-making season has been submitted for publication.

Co-operative work has been done with a manufacturer of bagoong, a fermented fish paste which is exported in considerable quantities. Recommended improvements in the method of manufacture have been submitted to the firm. Bacteriological and pilot plant work is also being done on bagoong with a view to shortening the process which at present is of six months duration for the better grades.

Samples of Philippine fishery products have been canned and set aside for periodic storage studies and for submission to Fish and Wildlife Service laboratories in the United States to note the effect of long distance transportation and cooler climatic conditions. Among the items canned have been yellowfin and striped tuna, bonito, dolphin or dorado, barracuda both fresh and smoked, Spanish mackerel, shrimp, oysters in brine and smoked, sailfish, gizzard shad, sardines, and carangids. Various sauces, brines, and oils have been added to the packs including spiced tomato, escabeche and soy sauce, coconut, cotton-seed and olive oil. Experimental packs of white barred tuna, *Kishonouella tonggol,* and dogtooth tuna, *Gymnosarda nuda,* have recently been prepared. These tunas are taken in considerable quantities in some parts of the Philippines but to our knowledge have not been commercially canned. The former is similar to yellowfin when canned and the latter has even a lighter coloured meat which gives promise of making a good quality canned product.

At the request of the Philippine Bureau of Fisheries, work is also being done on methods of canning fishery products that are suitable for use in the home. This is being done for the purpose of assisting the people so that fish that are taken by them in large quantities in certain seasons may be preserved for use during the periods of scarcity. These packs, which are put up in glass jars, include all the fish noted in the foregoing paragraph with the exception of shrimp, sardines and oysters.

Investigation by the Programme reveals that one of the chief obstacles to the establishment of commercial canning plants in the Philippines is the lack of an adequate can manufacturing plant and the excessive price of such cans as are available. The limited existing can-making equipment is old and the quality of the cans now being produced is not satisfactory for pressure-canned fishery products.

Tested recipes prepared by a technologist describing methods of utilizing fish caught in Philippine waters are being regularly published in several newspapers. The object is to stimulate the use of fish not now generally eaten such as tuna, sharks, lizard fish and other wholesome but unpopular species. Shark meat has been found to be best when cooked in an acidic medium or treated in such a medium before cooking. Soaking in lemon juice previous to frying, cooking in a creole sauce and use of a vinegar court bouillon were the preferred procedures. The acid helped to make the product tender and eliminated the "shark flavour" attributed to breakdown of urea in the shark flesh into ammonia.

By-Products

Samples of livers from fish taken by the Programme vessels as well as samples procured in the market have been analyzed for Vitamin A content. Included in the study are livers from 17 species of sharks; nine other elasmobranch types such as sawfish, angel sharks, guitar fish and rays; five types of tuna; Spanish mackerel, sailfish, barracuda, rainbow runner, groupers, and a few species of carangids. The results are now being compiled in a paper to be submitted for publication. To date no outstanding source of high potency livers has been encountered. The tiger shark, *Galeocerdo arcticus,* which can be obtained in quantities sufficient to furnish part of the Vitamin A requirements of the Islands, has a liver with a high oil content—up to 80 per cent—and the liver is very large—about 20 per cent of the total weight of the animal—but the Vitamin A potency of the oil is low, averaging around 3,000 I.U. per gram. Work is being done on other fractions such as cholesterol with a view to finding other by-products which would add to the value of the oil. At this time fish are sold in the round so that it is not feasible to collect livers from market fish.

Small pilot plant batches of sardine meal have been prepared and experiments with shark meat will soon be undertaken. It is not anticipated, however, that a fishmeal industry will be established in the Philippines for some time because the supply of fish for immediate consumption is not sufficient to meet the demand. For the same reason other by-products such as glue, pearl essence and other items are of no significance at present.

Hides of the large sharks taken by the Programme vessels are being experimented with to determine the possibilities of tanning them for manufacture into leather.

Fishing Gear

It was soon realized after the start of the actual Programme work in Manila that the storing, preservation, treatment, mending, and making-up of new gear to be used in experimental and exploratory fishing would require considerable effort and that the results of this work would be of value to the Filipino fishermen. A model net loft was, therefore, established where the nets for the Programme vessels are stored, tanned and mended, and new experimental gear prepared.

Research is being conducted to study the effect of various preservatives on abaca and other native fibres which can be used for the manufacture of fishing gear. Preservatives being used are pine tar, copper oleate, cutch-borneo, dura-nett II, tar and creosote, cuprinol, blood, bakawan bark, nigue bark, and bakawan and nigue bark in combination. A combination of samples of twines and webbings treated with these different preservatives are being tested in the waters of Manila Bay to evaluate the best method of preserving fishing gear in the Islands. Breaking strength as determined will be the basis for evaluating the efficacy of the treatment.

Because of the interest in new types of gear, a booklet showing the use of the otter trawl has been prepared and distributed to interested parties.

BIOLOGICAL SUCCESSIONS IN DISHARMONIC BAYS AND LAGOONS, AND THEIR IMPROVEMENT FOR FISHERIES PURPOSES

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On the coast of Japan there are a number of bays and lagoons of which the hydrological conditions are more or less peculiar and animal life is abnormal. The degree of disharmony depends chiefly on the form of the basins, the salinity and the dissolved oxygen content, which act together.

In such a bay with a basin sufficiently deep below the outlet to the open sea, the stagnation due to the summer temperature stratification alone may be sufficient to give rise to an oxygen-free azoic area in the deep stratum. A rich animal life, both pelagic and benthonic, may however be expected in the winter season when the whole layer is aerated by the overturn and circulation. Such caldera bays as Habu Bay (max. depth 19m., depth of outlet 4m.) in Osima of Tokyo Prefecture, and Yamakawa Bay (max. depth 49m., depth of outlet 8m.) in Kagosima Prefecture, are examples of this type.

In some lagoons where considerable differences in salinity between the surface and bottom strata exist, the stability of summer stagnation becomes great and the overturn due to the surface cooling is increasingly reduced. However, if the season of aeration is sufficiently long and the amount of oxygen not too small, a very large benthonic population composed of relatively few species (chiefly of polychaetes and bivalve molluscs) is usually found. If the oxygen condition becomes lower in the circulation season or a little higher in the stagnation season, polychaetes (*Prionospio pinnata* is a typical one) survive, because they are more tenacious than bivalves. When the surface salinity is very low, circulation never occurs, and the deep part of the basin remains permanently azoic.

In very shallow brackish water lagoons, the hydrological conditions are widely variable and the aeration and deoxygenation takes place irregularly. They are sometimes very richly populated (e.g. Kukusi Lake) but sometimes are very poor in life (e.g. Zinzai Lake). The black deposits have a strong reducing action and give rise to a microstratification of oxygen which affects the organisms seriously.

The following is an attempt, based chiefly on benthonic data, to classify the disharmonic bays and lagoons. It must, however, be noted that different strata of the same basin may belong to different types or subtypes.

(I) *Permanent azoic type.* The basin of this type has a depth so much greater than the outlet that wind disturbance does not reach the bottom. The salinity of surface water is much lower than that of bottom water. The inflow of sea water is relatively small, or limited chiefly to the summer season, or occurs on occasions on high water level such as are caused by storms. The deep water contains no oxygen throughout the year. Some brackish or marine animals are found on shallow bottoms only. Hiruga Lake and Suigetu Lake on the Japan Sea coast belong to this type.

(II) *Summer axoic type.* (i) Benthonic population, composed chiefly of polychaetes and molluscs, and sometimes very large, is present in the winter season but none in the summer season (Habu Bay, Yamakawa Bay, Kumihama Bay on the Japan Sea coast, etc.). (ii) Polychaetes only are found in the winter season, but none in the summer season (a part of Yosanaikai). (iii) Though not really azoic, a few polychaetes are the only survivors in the summer season, and abundant shells of bivalves, which were alive in preceding winters, are accumulated in the deposits (e.g. Nakano-umi).

(III) *Slightly disharmonic type.* There are also many other bays and lagoons in which neither permanent nor temporary azoic area exists. In such habitats, the number and kind of animal species composing the benthonic community may be used as indicators of the degree of disharmony.

There are also cases, in which a slight change in the topography or salinity may cause an ecological succession from one type to another. In Yosanaikai, a lagoon on the Japan Sea coast, the recent growth of the sand bar made the interchange of lagoon and sea water difficult. The decrease of surface salinity following this change hindered the overturn in the winter season. Varied evidence, especially the thanatological, indicates that this lagoon previously belonged to the summer azoic type, a large population including bivalves being maintained in the winter season. In recent years, however, it has become azoic for all seasons. Such changes naturally influence the life of fish, which lose food and shelter in the winter season when the surface temperature drops to freezing point. It was upon our advice that the water course was dredged in 1947 to make the outflow of the less saline surface water and the inflow of the sea water easier. By this procedure the benthonic life is recovering to the supposed former condition and the fish production is greatly improved. It is also expected that oyster culture may become possible as was the case formerly. If similar improvements should be successful in other lagoons, they may contribute to the fisheries of Japan.

As another example of an artificial succession, we may mention Nakano-umi, a lagoon formed by a sand-bar on the Japan Sea coast. The construction in 1930 of a breakwater for Sakai Harbour at the end of the bar increased the length of the outlet, and this acted to raise the water level and lower the salinity. Though we have no accurate data as to the fauna, there are sufficient reasons to believe that the oxygen condition deteriorated and the production especially of molluscs was so reduced that it aroused the complaint of the local fishermen. At present polychaetes are the only inhabitants of the deep basin in the summer season.

We think it appropriate to comment here on the so-called "Nigasiwo or bitter water" which occurs in some disharmonic lagoons on stormy days and does much damage to fish and other invertebrate animals. This is not a biological phenomenon, but is caused by the upwelling of oxygen-free bottom water (sometimes with the black deposits) on the windward side to compensate for the leeward drift of the surface water.

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AN ANALYSIS OF THE CONSTITUTION OF THE INTERTIDAL FAUNA AND FLORA OF THE ROCKY COAST OF NEW SOUTH WALES, AND SOME COMMENTS ON ITS RELATIONSHIPS TO THOSE OF OTHER TEMPERATE AREAS OF THE SOUTHERN HEMISPHERE

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[*Abstract*]

THE intertidal fauna and flora of the rocky, open coast of New South Wales shows a great similarity in basic pattern throughout its length (approx. 1,000 miles) and is undoubtedly all the one faunal province.

Typically this province shows an arrangement of the plants and animals into five, clearly marked, horizontal zones, each of which is marked by indicator species. With these indicator species a series of plants and animals is regularly associated and some of them are limited in their distributions to the horizon of the indicator species. Others occur more widely on the shore. The sequence of the associations remains, however, fundamentally the same along the whole coast despite variations in degrees of exposure, latitude, and the types of rocks forming the substratum.

These Zones (enumerating them from the lower to the higher levels) are as follows:—

(1) A Kelp Zone with *Phyllospora* and *Ecklonia* as indicator species.
(2) A *Pyura* Zone with the Ascidian *Pyura* as the dominant form of life.
(3) A *Galeolaria* Zone with the Serpulid worm, *Galeolaria* as the dominant.
(4) A Barnacle Zone in which four species of barnacles are found.
(5) A Littorinid Zone with the two small molluscs *Melaraphe* and *Nodilittorina* in the ascendancy.

The extent and variations of these zones with changes in exposure and latitude and various edaphic factors was discussed briefly.

Only two or three of the indicator species do not extend throughout the length of the coast of New South Wales and notably only a few of the commonest animals associated with them have limited ranges. These were discussed.

This faunal province is not, of course, limited by the political boundaries of New South Wales, but extends only a little distance to the north of the Queensland border and probably only a short distance round the Victorian coastline, at its eastern end. The exact limits are not known here, but an intermingling of southern forms from the Flindersian Province is already becoming apparent at Bermagui on the coast of New South Wales.

There is a strong resemblance between the patterns of zoning of the littoral animals of New South Wales and South East Africa (as described by T. A. Stephenson *et al*).

(Much of the matter presented in this paper was included in "A Study of Certain Aspects of the Ecology of the Intertidal Zone of the New South Wales Coast", by W. J. Dakin, Isobel Bennett and Elizabeth Pope, *Australian Journal of Scientific Research*, Series B, Vol. 1, No. 2, pp. 176-230, 1948, which should be consulted.—Ed.)

DISCUSSION

Dr. Cottam asked if *Zostera* had fluctuated in quantity since 1930, pointing out that *Zostera* on the American coasts had declined markedly in the years 1930-31, with serious consequences ecologically. In reply Dr. Pope stated that there had been no variance in Australia, and referred to the absence of disturbance by marine mammals. Dr. M. Johnson called for standardization of terminology. Dr. R. C. Miller referred to a terminology being evolved, using the central intertidal zone as a starting point.

STUDIES ON PLANKTON OF THE BERING AND CHUKCHI SEAS AND ADJACENT AREAS

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INTRODUCTION

INVESTIGATIONS on the zooplankton of the Bering Sea have been most fragmentary, and there appears to have been no studies whatever dealing with plankton in the open waters of the Chukchi Sea (also known as Chukotsk Sea) which is part of the Arctic Ocean lying north of the Bering Strait.

The Canadian Arctic Expedition of 1913-1918 issued a number of short taxonomic reports dealing with marine plankton collections taken along the Alaskan coast. See especially Willey (1920).

The present study on the biology of the plankton is based on two series of net collections each taken simultaneously with hydrographic observations made by the U.S. Coast Guard Cutter *Chelan* from July 26 to August 24, 1934, and the U.S.S. *Nereus* from July 27 to August 12, 1947.

TABLE 1

NUMBERS OF PRINCIPAL PLANKTON ORGANISMS TAKEN BY THE U.S.S. *NEREUS* IN THE BERING AND CHUKCHI SEAS 1947 (ADJUSTED TO 60 METRES VERTICAL HAUL)

Station	[illegible]	[illegible]	N5	N6	N7	N8	N9	N10	N11	[illegible]	N13	N14	N15	N16	N17E	N21	N22	N23	N28	N30	N46
Acartia longiremis	297	113	4,115	5,584	2,671	170	70			5	152	1			1	6	296	3,530	1	68	2,605
Acartia nauplius				1,088	1,972	85	140			1								974		135	1,146
Calanus cristatus	5							1											1		
C. finmarchicus	30	341		26	175	75	257	25	39	74	8	7	11	6	8	29	213		104	60	9
C. tonsus	1	1					4	64	4	5			1		1						
Centropages mcmurrichi																3		111			7
Epilabidocera amphitrites				1												1					
Eucalanus bungii bungii	21	6					3		1							8	9				19
Eucalanus nauplius	88	57					140	172		116							1		1	1	
Metridia lucens		[illegible]						7	[illegible]				1	1	2				1		
Microsetella															1				1		
Oithona similis	12,223	1,644	1,037	798	2,076	8,456	7,186	3,272	[illegible]	[illegible]	236	457	1,455	522	484	2,531	6,065	2,515	2,551	2,774	[illegible]
Oncaea borealis					1																
Pseudocalanus minutus	128	2,062	1	4,786	4,785	957	1,820	2,153	[illegible]	[illegible]	76	1,523	4,137	1,045	761	2,359	2,465	1,947	1,012	677	[illegible]
Tortanus discaudatus			2							1						1				1	
Calanoid [illegible]						511	1,750	1,033	[illegible]	[illegible]	114	1,980	2,334	730	691		2,465	1,582	92	609	[illegible]
Euphausiid	1	2	2					1									2				
Euphausiid larva			155						2				1			2					
Euphausiid egg			1			396	70														
Amphipod	10	1		1	13	8	19	39	[illegible]	1	2	1		1	1		3		6	3	6
Evadne																189		365			
Podon																189		486			
Appendicularia		284	1			3,420	1,260	258	[illegible]	[illegible]	358	2,129	849	107	78	1,038	556	1,826	92	1,962	[illegible]
Balanus nauplius	172				4	8		173	[illegible]	1		726	2,334	4	484	755		1	92		[illegible]
Balanus cypris	44							1	[illegible]	1	10	7	1,803	1	277	189	1	111		1	[illegible]
Crab larva	16	1	4	1	4		6	4	[illegible]		1	1	1		1		1	4	2		[illegible]
Annelid larva				1	6		2				1	606	5,248	1	1	189	1	988		203	[illegible]
[illegible] larva	132	113	155	73	7,059	1,960	1,820		[illegible]	464	1	152	212	1		3,397	3,744	2,434	184	1,421	[illegible]
Veliger larva	658	1,701					70			1											3,960
Chaetognath 0-8mm	19	11	78	334	364	47	1	8	[illegible]	27	2	5	49	6	9	44	93	19	13	19	
Chaetognath 8-15mm	160	6			4		2		[illegible]	6	5	7	1		1		4	12	14	19	
Chaetognath 15mm	13			1	26		85	4	2		1	1		10	1		15			3	
Bipinnaria	44		7													189		1			521
Echinopluteus			1	162,739	1	170	2,030			290						2,170	3,252	609		11,164	
Ophiopluteus	219				623	257	420			174	1					1,321	197	1		118	7,502

The *Chelan* occupied 102 plankton stations distributed along lines covering extensive stretches in both offshore and coastal waters of Bering Sea from the Aleutian Islands north through the Bering Strait to latitude 66° 46′ N., longitude 170° 01′ W. (Figure 1). The *Nereus* occupied seven plankton stations, on a line from the Hawaiian to the Aleutian Islands, one at Unimak Island and 20 from the Pribilof Islands northward into the Arctic to the edge of the polar ice pack at 72° N. Only the stations from the Aleutian Islands northward will be here considered in detail (Figure 3).

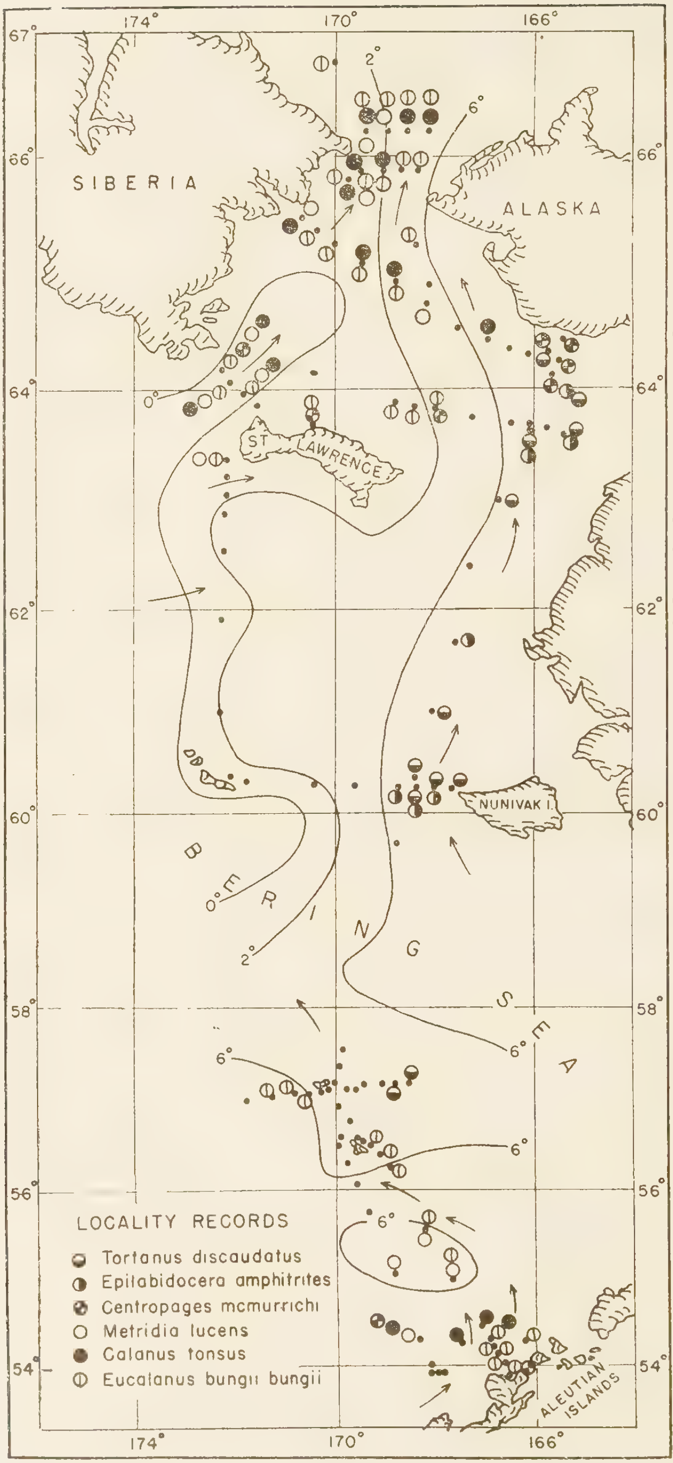
The collections are of special value because of the extensive area covered in so short a period of time on each cruise. They contribute materially to our slowly accumulating knowledge of these remote areas especially with respect to the study of animal production during the summer; and to an over-all picture of the distribution of both permanent and temporary plankton as related to hydrographic features. A report pertaining to the *Chelan* collections was prepared for the Coast Guard (Johnson, 1934a).

The present report presents new data from the *Nereus* cruise, and it is desirable at the same time to integrate the results of the two cruises taken in much the same areas, but thirteen years apart, and to make the results generally available to interested civilian investigators. Tables for the 1934 plankton counts, including the more infrequent forms not here discussed can be found in the Coast Guard report. Table 1 includes counts of the principal forms taken in 1947. Station N32 is omitted from the table since the sample was not complete but it is included in the figures for locality records. The physical and chemical data for the 1934 *Chelan* cruise are discussed in detail by Barnes and Thompson (1938), and the *Nereus* cruise by LaFond, Dietz, and Pritchard (in press). The phytoplankton collected simultaneously with the zooplankton by Dr. L. D. Phifer during the *Chelan* cruise was studied by Phifer (1934). The net samples for 1947 were collected by E. C. LaFond, and R. S. Dietz. Dorothy Rubright assisted in analysis of the 1947 material.

Procedure: The *Chelan* used a 25 cm. net constructed of No. 20 bolting silk. The hauls were made vertically from a depth of 25 metres to the surface while the ship was hove to. The *Nereus* employed a 40 cm. net 1·5 metres long, constructed of No. 8 bolting silk, and at all stations except those in the Hawaiian section it was operated vertically from the bottom, usually 40 to 60 metres, to the surface.

The counts of organisms obtained for each haul give only relative concentrations of the more numerous and slowly moving forms especially copepods and larvae, but the pattern of distribution and its correlation with hydrographic features are such that the distribution and numbers are believed to give a fairly accurate portrayal of the major prevailing summer communities.

Plankton volumes were determined only for the 1947 cruise. In Figure 3 is given the relative volume (measured by displacement) of total plankton adjusted to 60 metre hauls for comparison. Both zoo- and phytoplankton are included, hence the figures represent total particulate organic material screened from the water by means of this type net. Usually the bulk, which in no case was large, was made up of zooplankton, but at stations N11, N14, and N16 the bulk was due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NUNIVAK I.
BERING SEA
ALEUTIAN ISLANDS
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2°
6°
LOCALITY RECORDS
Tortanus discaudatus
Epilabidocera amphitrites
Centropages mcmurrichi
Metridia lucens
Calanus tonsus
Eucalanus bungii bungii

FIG. 1.—Distribution of certain copepods in 1934. The *Chelan* plankton stations are shown as small dots. The isotherms (Centigrade) are for the 25 metre depth.

mainly to diatoms especially *Thalassiosira rotula, Thalassiosira nordenskioeldii, Fragilaria striatula,* and *Nitzschia seriata.* At N16 *Fragilaria* was overwhelmingly dominant.

In all cases the volumes are certainly minimal, since much of the finest material passes through the meshes of the net, and larger fast-swimming forms escape it.

THE ZOOPLANKTON POPULATION

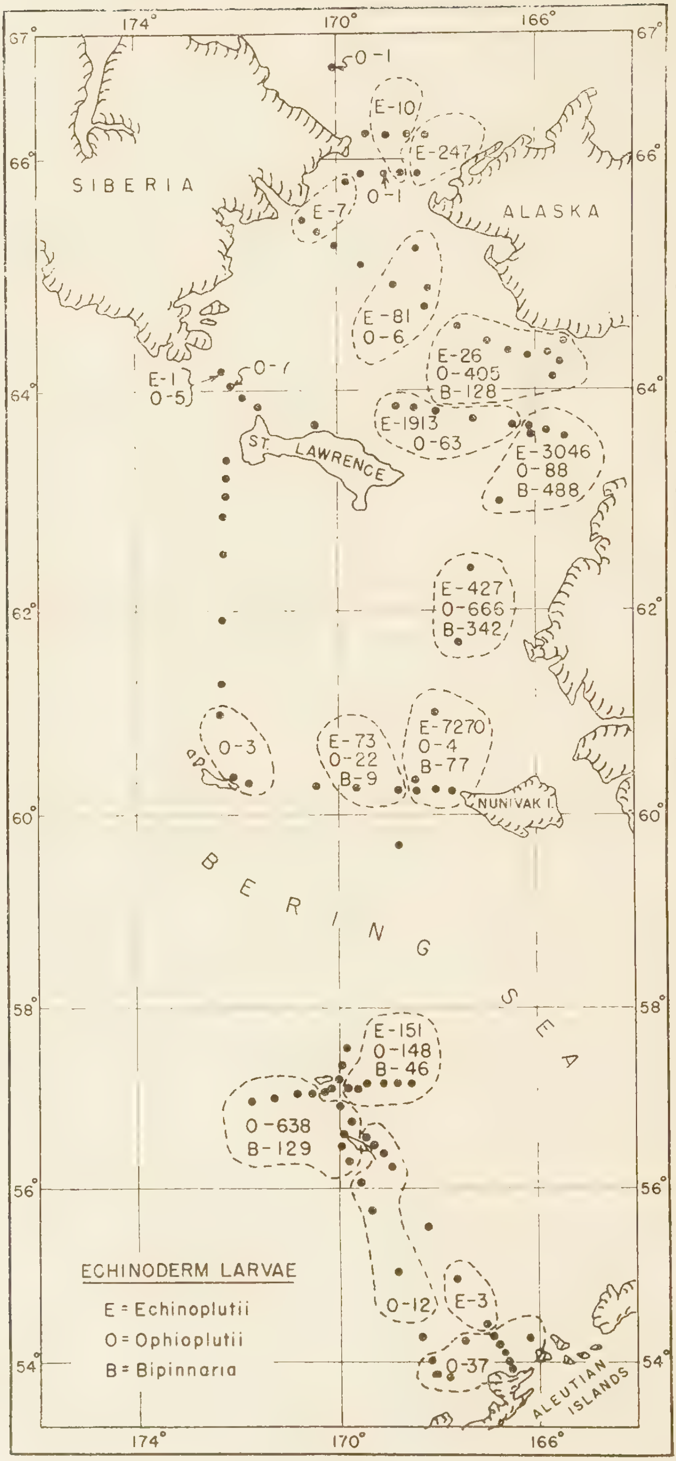
Copepods constituted the major constituent of the plankton on both cruises though echinoderm and clam larvae, and appendicularians were often dominant.

From the following list of copepods certain of the species have been included in Figures 1 and 4 because of their characteristic distribution in relation to hydrographic features of inshore or offshore waters:

Acartia clausii Giesbrecht was taken in the *Chelan* cruise only in the vicinity of Nome, Alaska at stations C32, C33, and C57, and none were observed in the *Nereus* collections. This species thrives best in a neritic habitat with warm water of reduced salinity, and although not typically an Arctic species, it was reported by Willey (1920) in his analysis of the Canadian Arctic Expedition's plankton, from as far north as Point Barrow, Alaska. This northward extension of distribution to latitudes, unusually high for the species, is correlated with the northward flow of Bering Sea water through the Straits as evidenced by the hydrographic observations. Other fragments of biological information which will be mentioned below lend support to this contention. *A. clausii* is a common copepod along the Pacific coast and is abundant at times at La Jolla, California.

Acartia longiremis (Lilljeborg) is widely distributed in the surface water of the Bering and the Chukchi Seas. Adults were taken at 55 per cent of the *Chelan* stations and 85 per cent of the *Nereus* stations. If the species were represented at all stations where *Acartia* juveniles and nauplii were taken, the number of *Chelan* stations of occurrence is increased to 75 per cent. It is probable that the larvae and juveniles were mainly of this species. *A. longiremis* is more oceanic than *A. clausii,* and its regular distribution extends far into the Arctic and for that reason its presence north of the Bering Strait would not necessarily indicate that its presence is a northward extension of the Bering Sea population by way of the Strait. Its distribution in these surveys places it mainly with the neritic community on the Alaskan coast. There were decidedly fewer on the Siberian side. In 1947 active reproduction was taking place especially in areas of Norton and Kotzebue Sounds and Unimak Island.

Calanus cristatus (Kröyer). This unusually large copepod occurred at eight *Chelan* stations, particularly in the Bering Strait, and between Siberia and St. Lawrence Island. In 1947 it occurred at three stations, one near the Pribilofs, and two in the western portion of Bering Strait. It is known to be one of the important constituents of the North Pacific offshore and deep-water plankton. Samples examined from deep water of the Gulf of Alaska, and south of the Aleutian Islands indicate that it is one of the most numerous among the larger copepods there. It was present in *Nereus* samples from Lat. 43° 29′ N., Long. 171° 00′ W., and in 1939 two specimens were found in deep hauls by the *E. W. Scripps* 300 miles offshore in the latitude of Pt. Fermin, California.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ST. LAWRENCE
NUNIVAK I.
BERING SEA
ALEUTIAN ISLANDS
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E-247
E-7
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E-81
O-6
E-26
O-405
B-128
E-1
O-5
O-1
E-1913
O-63
E-3046
O-88
B-488
E-427
O-666
B-342
O-3
E-73
O-22
B-9
E-7270
O-4
B-77
E-151
O-148
B-46
O-638
B-129
O-12
E-3
O-37
ECHINODERM LARVAE
E = Echinoplutii
O = Ophioplutii
B = Bipinnaria

FIG. 2.—Quantitative distribution of echinoderm larvae. Average number of specimens taken in 25 metre hauls at stations enclosed in broken lines. U.S. C. G. C. *Chelan* 1934.

Calanus finmarchicus (Gunner) was taken at fifty *Chelan* stations distributed along all the sections with the exception of that south of St. Paul Island. It is probable that its distribution in that area is to be looked for below the level at which the net fished, for it is known to seek relatively deeper water in the intermediate layers when this is possible. It was present in small numbers at all but one of the *Nereus* stations.

The occurrence of *Calanus tonsus* Brady is shown in Figures 1 and 4. Its greatest frequency was in the colder waters flowing from the west and in the Straits northward into the Arctic. It is perhaps second to *Calanus finmarchicus* in importance among the large copepods of the region.

Centropages mcmurrichi (Willey) was present at widely separated stations (Figures 1 and 4). This species evidently prefers the inshore conditions, but may be expected also in more oceanic waters. Willey (1920) found it, and also the following species in collections from north of the Bering Strait on the Alaskan side.

Epilabidocera amphitrites (McMurrich) was taken only in small numbers mainly in the larval stages. The seven *Chelan*, and two *Nereus* stations where it was taken are in Alaskan neritic waters (Figures 1 and 4). Willey (1920) records it from latitude 68° 30′ N. within the Arctic circle on the Alaskan coast. Southward it ranges to San Francisco Bay (Esterly, 1924).

In the study of *Chelan* samples, it was brought out that only the northern variety of *Eucalanus bungii* (see Johnson, 1938) occurred in the Bering Sea area. The *Nereus* series of samples verify this finding. The extensive area covered by the *Nereus* makes possible a further comparison of that interesting species.

In the series of stations occupied between the Aleutian and Hawaiian Islands, it was found that only the northern variety, *Eucalanus bungii bungii* was present at 43° 29′ N. latitude, and at stations north of that point, whereas at the next station south (38° 49′ N. latitude) it was almost completely replaced by the southern variety, *Eucalanus bungii californicus*. In the sample taken at this station only two adult specimens of the northern variety were found among forty specimens of the southern variant. The *Nereus* bathythermograph records show about 5° C. difference in surface temperature between these stations. On the west coast of North America the two varieties overlap along the Oregon coast and southward to Cape Mendocino, California.

E. bungii bungii is a major constituent in the Gulf of Alaska plankton, and is one of the most common species in the deep northern waters of Japan (Tanaka, personal communication, 1948).

The horizontal distribution of *E. bungii* in the Bering Sea indicated that it belonged typically to the western deeper portion of the sea, and as such was found mainly in regions characterized by north-eastward moving water of higher salinities, and lower temperatures (Figures 1 and 4). For example, it was found between Unalaska Island and the Pribilof Islands, and also west of the latter, and to the north along the Siberian coast, and in that portion of Bering Strait which is most characterized by water from the south-west. One might expect to find the species along the section from St. Lawrence Island to St.

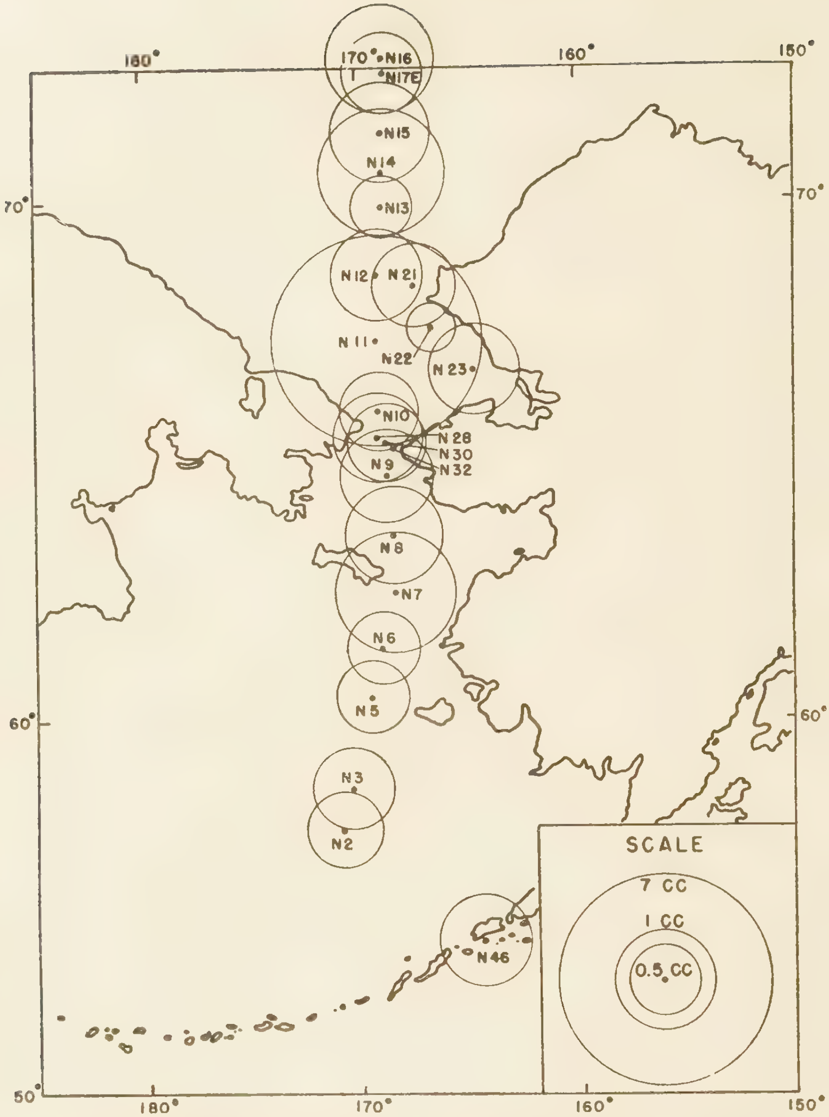
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FIG. 3.—Plankton displacement volumes adjusted to 60 metre hauls. The 1947 U.S.S. *Nereus* station numbers are also indicated.

Matthews, but here the surface waters were sparsely populated by any species. The 1947 samples show a somewhat more northern and eastern distribution than occurred in 1934. All stages of larval development were found on both cruises indicating successful reproduction in July and August. The distribution of the species and the proportions of developmental stages in the Bering Sea for 1934 have been reported elsewhere (Johnson, 1938). In 1947 nauplius larvae were taken at various stations up to N12 off Cape Lisburne.

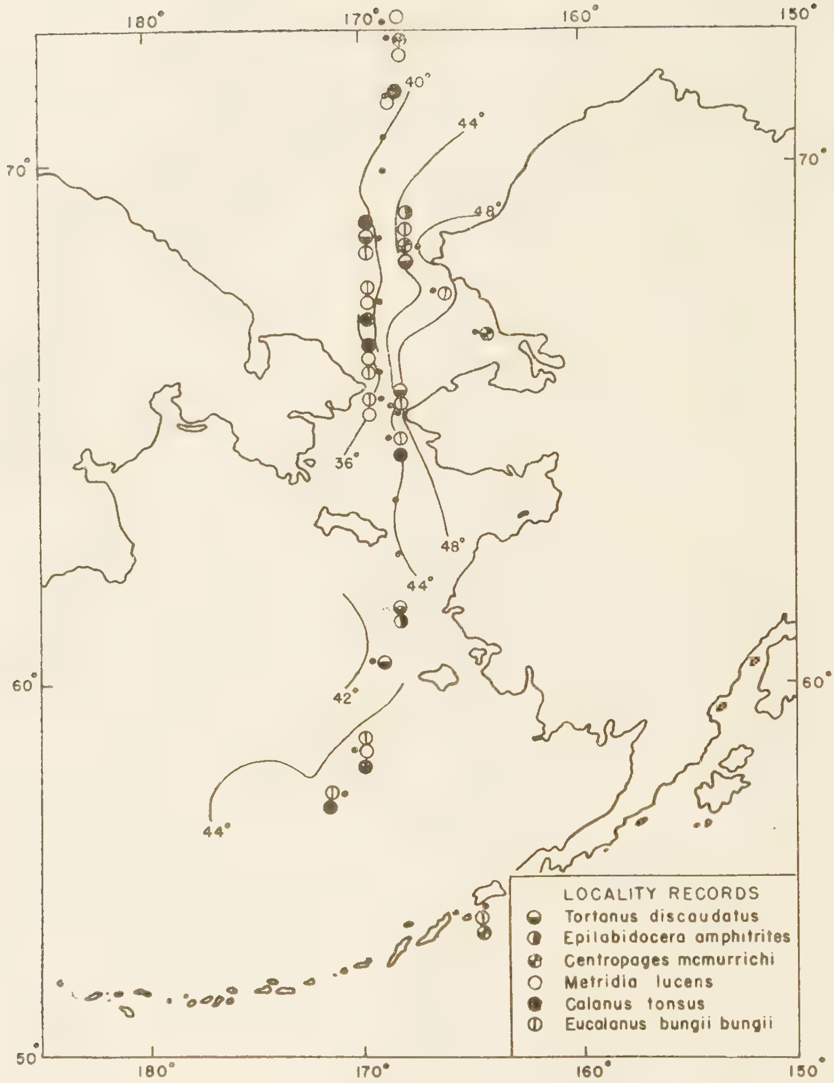
Eurytemora herdmani (Thompson and Scott) was noted only near the Pribilof Islands and off the entrance to Norton Sound. It was not found in 1947. The Canadian Arctic Expedition had it at stations in the Bering Sea and along the Arctic coast of Alaska and Canada.

Metridia lucens Boeck was taken at some of the more oceanic stations, placing it in the community characterized by *Eucalanus bungii, Calanus tonsus,* and *C. cristatus* (Figures 1 and 4). It is a wide ranging species occurring in offshore waters from Southern California to the northernmost *Nereus* station at the edge of the Arctic ice. A number of the specimens included in the table were juveniles, and had not yet developed specific characters, but in each instance where identification was possible, only *M. lucens* was present both in 1934 and 1947. The absence of the "Arctic" species, *M. longa* (Lubbock), in the Bering Sea in summer might indicate an absence of southward transportation of Arctic species through the Bering Strait, in summer. However, it was also absent from the *Nereus* stations far north of the Strait. It has, however, been reported by Campbell (1929) from the Vancouver Island region, by Marukawa (1928) from the Japan Sea and by Wilson (1942) chiefly in the north-western part of the north Pacific. Willey (1920) found it at stations situated only north of the Bering Strait.

Microsetella sp. was represented only as juveniles between the Aleutian and Pribilof Islands and in the Bering Strait in 1934, and in the Strait and in the Arctic in 1947.

Oithona similis was found by Willey (1920) to be generally distributed over the area covered by the Canadian Arctic Expedition. In the present investigation Table 1 shows clearly the abundance and extensive distribution of this little copepod over the whole area covered by the *Nereus*. At only one *Chelan* station was it absent from the collection. A large number of larvae, which are easily identified by reference to the work of Oberg (1906), were everywhere abundant or well represented except at three stations on the Siberian side of the Strait, showing that an extensive reproduction was taking place in all sections during the 1934 cruise. (The coarse meshed net used in 1947 apparently permitted these tiny larvae to escape, since very few were found.) This species must be considered a very important constituent of the surface plankton for the whole area during summer. It is probable that *Oithona* frequently plays a greater role in the plankton community than may be indicated in many plankton investigations where the coarse meshed nets employed are designed to catch only the larger animals. Its widespread distribution in the Bering and Chukchi Seas is in keeping with its well-known eurythermic and euryhaline character.

Oncaea borealis. These small copepods appear in general to belong mainly to that part of the area with the higher salinities and lower temperatures. Willey (1920) found *O. conifera* only along the Arctic coast.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LOCALITY RECORDS
Tortanus discaudatus
Epilabidocera amphitrites
Centropages mcmurrichi
Metridia lucens
Calanus tonsus
Eucalanus bungii bungii

FIG. 4.—Distribution of certain copepods in 1947. The *Nereus* plankton stations are shown as small dots. The isotherms (Fahrenheit) are for the surface.

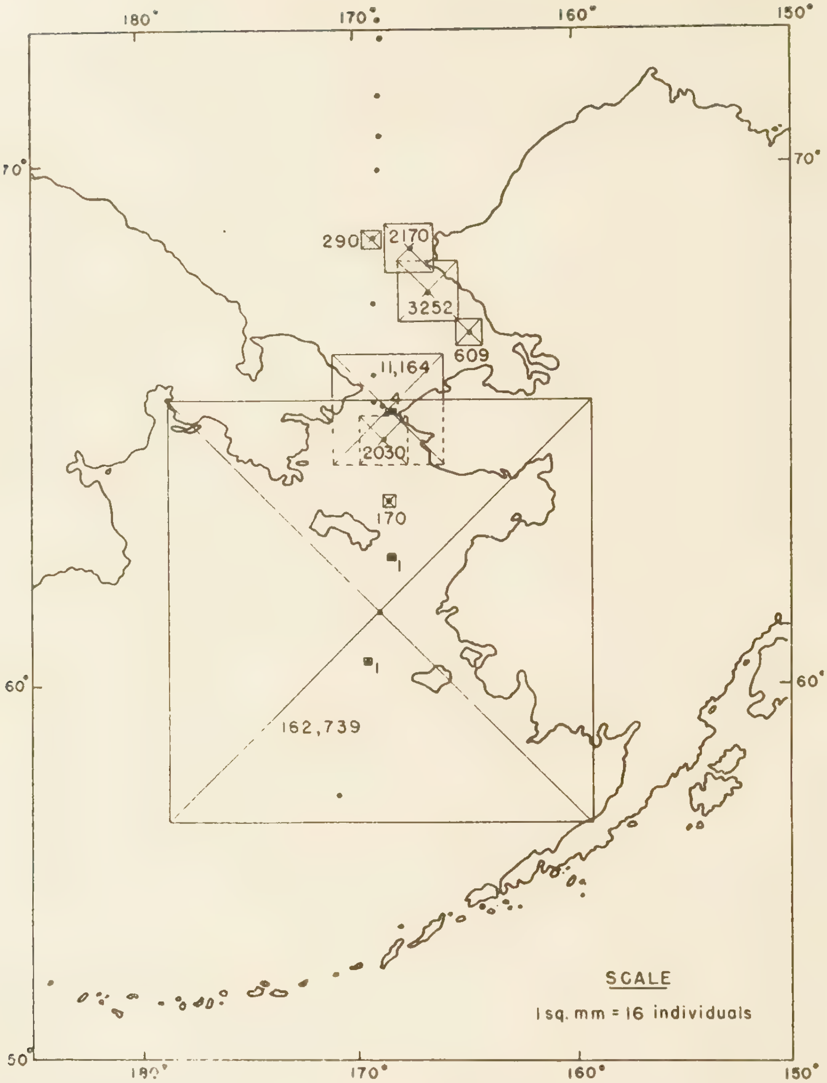
Pseudocalanus minutus (Kröyer). What was said above for *O. similis* applies rather well for this species also. The numbers were, however, somewhat less, and relatively fewer adults were taken. The greater vertical range of maximum distribution characteristic of this species as compared with *O. similis* would explain its fewer numbers in shallow plankton hauls, though the shoal water over much of the area would tend to keep it within the range sampled by the net.

Tortanus discaudatus (Thompson and Scott) was present only in waters of neritic and estuarine character along the Alaskan coast except at N12 off Cape Lisburne (Figures 1 and 4). On the west American coast it has a wide distribution, having been found as far south as La Jolla, California (Johnson, 1942). It is, however, not confined to the American Continent as formerly indicated for it has now been found also in the coastal waters of Northern Japan (Mori, 1937). But in the absence of thorough surveys in neritic waters along the coast of Siberia it is not possible to judge whether the connection is by way of the Bering Strait or to the south along the Aleutian Peninsula. Its eggs appear especially adapted for flotation (Johnson, 1935a) but their resistance to adverse conditions have not been studied. At temperatures of 10-12° C. they hatch in about four to five days. In tests the empty cases resisted decay over a period of at least 95 days. Thus if the eggs can remain dormant this long they would be accorded good surface protection during that time and might be transported considerable distance across areas adverse to the adults.

Among the pelagic larvae of bottom living animals, none were so conspicuous as certain echinoderm larvae. In 1934, practically the whole eastern area of the Bering Sea gave abundant evidence of heavy echinoderm spawning. Very few larvae were taken anywhere on the Siberian side. No larvae of Holothuroidea were found, though some early auricularia may have entered into the counts of bipinnarian larvae. The absence of holothuroidean "doliolaria" larvae may be accounted for by a short spawning period coupled with a relatively short pelagic life during which time the larvae float at the immediate surface as has been observed in Puget Sound.

Echinopluteus larvae of echinoids were well distributed over the eastern section (Figures 2, 5). The maximum number for one haul was about 162,000 in 1947, and 15,000 in 1934. It is significant that in 1934 the largest numbers were taken off Nunivak Island at stations C24 and C91, which are closely adjacent, but were occupied eleven days apart. Large numbers also occurred along the line from Nunivak Island to Nome, especially at the entrance to Norton Sound. On the Siberian side, only relatively few larvae were taken, but sufficient to indicate that a fair amount of spawning had occurred near the coast.

In 1947 echinoplutei were taken from station N5 northward to N12 (Figure 5). The greatest numbers occurred in the same general area as in 1934, i.e., off Cape Romanzof, and were perhaps the product of recent spawning in or near the area where caught, since the larvae were mostly in the 4 arm stage. Other successful *Nereus* hauls were in water with considerable thermal stratification, but in the band of relatively warm surface water extending out from the Alaskan Coast. Immediately north of the Bering Strait (stations N10, N27, and N11) where the surface isotherms are bent towards the east by cold water flowing along the western portion of the strait, no echinoplutei were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SCALE
1 sq. mm = 16 individuals

FIG. 5.–Echinopluteus. Numbers per haul, adjusted to 60 metre vertical hauls. U.S.S. *Nereus*, 1947.

taken, but at stations N12, N21, and N22, where the warm water from the Cape Lisburne and Kotzebue Sound areas is again felt at the surface, the larvae again appear. They apparently have drifted out with the surface water from the east.

Specific identification of the echinoplutei was not made, but in most samples the larval skeleton was preserved sufficiently to indicate the larval type. Examination of numerous specimens revealed only larvae with fenestrated bars in the post-oral and postero-dorsal arms, and with the body, and recurrent rods forming a calcareous basket similar to the clypeasteroid, *Dendraster excentricus*. The basket, however, appeared to be somewhat more open than in that species from Puget Sound, and the lower ventral transverse rods were not seen, but these rods apparently do not always develop until late in the larval life. The type of bottom occurring in the area of abundant larva is fine sand which is a favourable habitat for sand dollars.

From this survey of echinoplutei in the plankton, it is evident that the shallow waters of the Bering Sea and Alaskan coast must abound in adults of these animals or that the spawning season is especially abrupt and intense during this time of year. The Canadian Arctic Expedition found *Echinorachnicus parma* in water of 24 metres at 59° 24′ N., 165° 11′ W. (Clark, 1920).

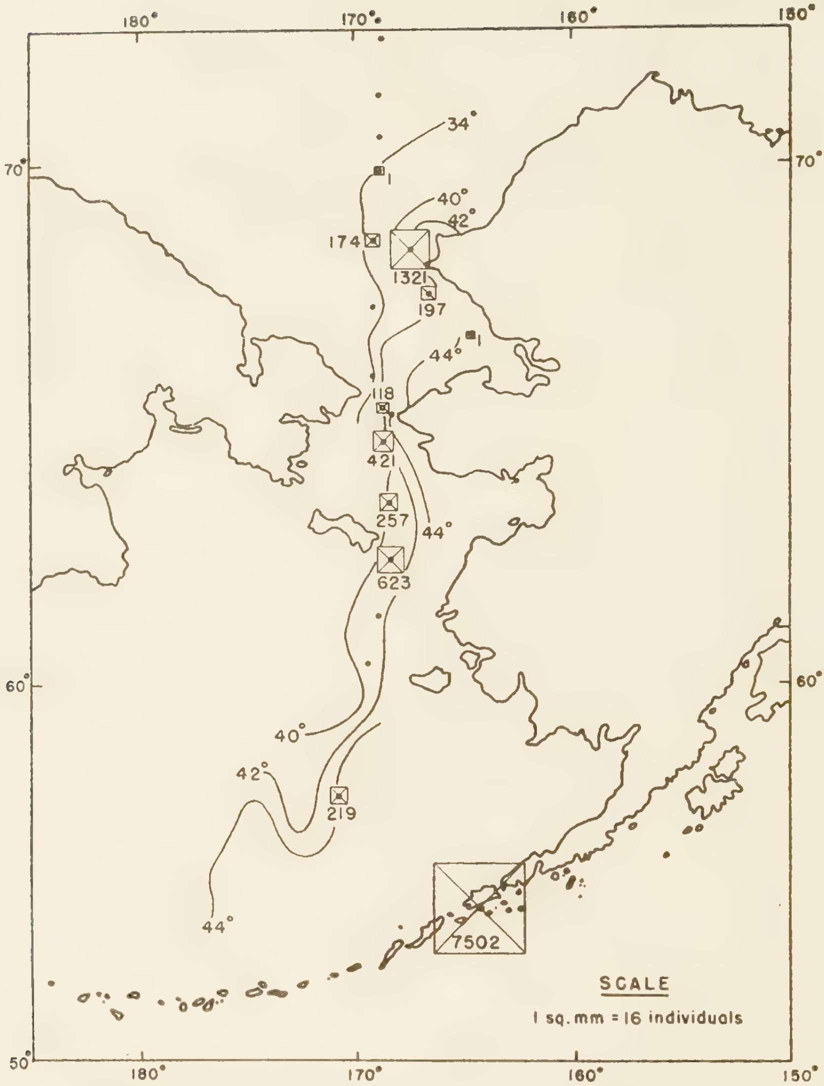
The *ophiopluteus larvae* of the brittle stars were more widely distributed, but less abundant, than were the echinoplutei. Like the latter, they were also characteristic of the warmer water of Bering and Chukchi Seas (Figure 6). Concentrations ranging up to 1,515 per haul were found in the region of the Pribilof Islands in 1934. Large numbers were found near Unimak Island in 1947.

It is strikingly noticeable that the ophioplutei, though having their optimum development in rather strongly neritic waters, occurred at 55 per cent of the stations and ranged into areas where few or no larvae of other echinoderms were taken.

Bipinnarian larvae of sea stars were less well represented, but were conspicuous in the plankton from the Pribilof Islands northward along the Alaskan coast to the region of Nome. The largest single catch, 1,030 individuals, was made in 1934 at the entrance to Norton Sound. None was found in the sections with higher salinities and lower temperatures. In 1947 they were poorly represented except at stations N46, N2, and N21 in the regions of Unimak Island, the Pribilof Islands, and Cape Lisburne.

Annelid larvae were found widely distributed in the area. The maximum number caught was at *Chelan* station 30, in Norton Sound, where 10,109 specimens were taken; 9,234 of these were mitraria larvae. Other hauls taken in this same area of diluted warmer water and in the Pribilof Islands regions were rich in annelid larvae. The larvae were absent or only poorly represented in the Siberian waters, and in the section south of St. George Island.

Lamellibranch larvae. The presence of especially large numbers of lamellibranch larvae gave evidence of abundant spawning during both cruises. In 1934, they were found at 82 per cent of the stations and large catches were made especially in the area off Norton Sound to the Siberian coast, and also at the stations to the east and west of St. Paul Island. Smaller catches were made in the narrow portion of Bering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118
421
257
623
219
7502
SCALE
1 sq.mm = 16 individuals

FIG. 6.—Ophiopluteus. Numbers per haul, adjusted to 60 metre vertical hauls. The isotherms (Fahrenheit) are for the 25 metre depth. U.S.S. *Nereus*, 1947.

Strait, and in the sections between St. Lawrence, St. Matthew, and Nunivak Islands. In 1947, 95 per cent of the stations yielded larvae, and hauls were especially rich near Unimak Island, and off Norton and Kotzebue Sounds, but considerable numbers were also taken in the open water off Cape Lisburne, and a few occurred clear up to the edge of the Arctic ice.

Though the largest catches were made in the more neritic waters, yet these larvae were less confined to such waters than were any other larvae except barnacle larvae.

Barnacle larvae were well represented over most of the area (Figure 7). In 1934, the greatest concentration was in Bering Strait, and in 1947 it was far to the north at station N15. It is of special interest to note that the chief plankton constituent at station N15 was barnacle larvae, mainly nauplii, but also cyprid stages (Table 1). Other stations in the Chukchi Sea yielded many barnacle larvae.

The occurrence of decidedly greater numbers of barnacle larvae in the northern sections may indicate that the main season of spawning had already taken place in the southern sections before the beginning of the cruise, July 26, and that most of the larvae had assumed the sessile stage or had been sufficiently dispersed to leave the waters only sparsely populated. It is probable that the spawning season progresses gradually northward with the advance of spring and summer. In the San Juan Island region of Puget Sound the height of spawning is in March and April with a temperature range of about 7° to 8·5° C. (Johnson, 1932). Another factor which must necessarily be taken into consideration in the distribution, and concentration of the pelagic larvae of this and other invertebrates is the extent and proximity of suitable substratum for attachment and survival of an extensive community of the adult stages. Much of the Bering Sea area has mud-sand bottom which is unfavourable for attachment.

However, near N15 in the Arctic a rocky area is shown in the *Nereus* chart of the bottom and at N13 a bottom photograph indicates coarse material. Hence, the larvae may have been produced quite locally.

The occurrence of many planktonic larvae of bottom-living animals at the northern stations is of interest, since it is common for many Arctic benthic animals to produce their young fully or nearly developed. In the Arctic barnacles of the genus *Scalpellum*, for example, the larvae are retained in the mantle cavity up to the cyprid stage.

Crab larvae were nowhere abundant, but in 1947 they occurred consistently at nearly all stations northward to N15 but with greatest numbers in the region of Unimak Island and the Pribilofs.

Fish eggs and *larvae* were surprisingly scarce. A few eggs were taken at stations N5 and N22, and larvae at N2.

The *cyphonautes larvae* of Bryozoa, which are so characteristic of neritic plankton farther south, were strangely absent from the catches during both cruises.

Other characteristic plankton animals included the chaetognaths, rotifers, and *Noctiluca.*

Sagitta sp. was most abundant at stations in the Bering Sea, but was distributed all the way to the northernmost station in the Arctic. Both young and adults were present indicating reproduction was taking place especially off the entrance to Norton Sound.

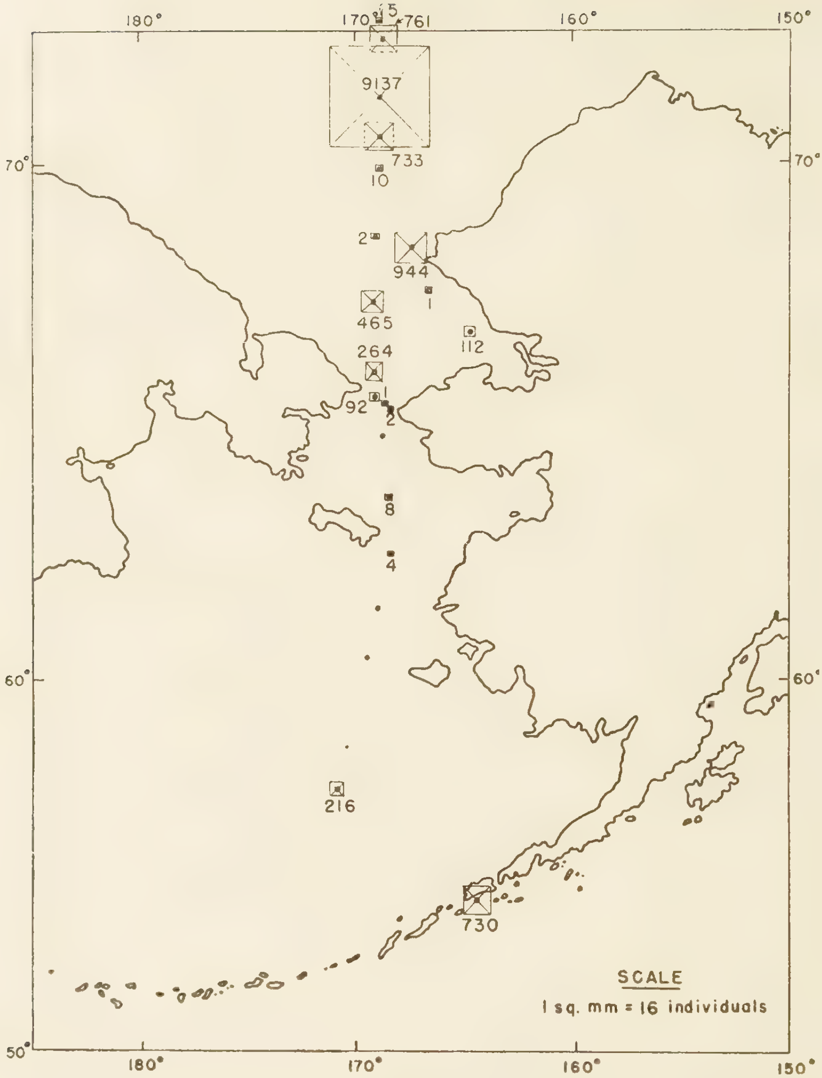
180°
170°
15
761
160°
150°
9137
733
10
70°
2
944
1
465
264
112
1
92
2
8
4
60°
216
730
SCALE
1 sq. mm = 16 individuals
50°
180°
170°
160°
150°

FIG. 7.—Barnacle larvae. Numbers per haul, adjusted to 60 metre vertical hauls, U.S.S. *Nereus*, 1947.

Rotifers were observed only in 1934, and occurred principally near the Pribilofs and Norton Sound. Very few occurred in Bering Strait or at the more westerly stations, and in the section south of St. George Island.

Noctiluca was present only on the Alaskan side in 1934, particularly in the Nome-Norton Sound region. Small numbers were taken at stations in the vicinity of the Pribilofs, and fewer south to the Aleutian Islands.

Podon was taken at nine stations and *Evadne* at four stations in 1934, all in the Nome-Norton Sound area, and in 1947 only at stations N21 and N23.

Discussion

The U.S. Coast Guard cutter *Chelan* carried out hydrographic observations at 120 stations, and the U.S.S. *Nereus* at 39 stations, including those where net hauls were taken.

From the hydrographic reports we learn that in the Bering Sea and Strait and in the Chukchi Sea there is a marked decrease in temperature from east to west during July and August. Along the Alaskan coast to the region of Point Spencer, surface temperatures were above 9° C. In 1934 the 9° isotherm paralleling the coast was situated near the western tip of Nunivak Island, and a tongue of this relatively warm water extended south-westward to include water just to the south of the Pribilof Islands. Along the Siberian coast surface water was from 3° to 6° C., and extended from St. Lawrence Island west of the Diomedes to the Arctic. Subsurface temperatures roughly paralleled the surface isotherms, and also in part the bottom topography. The 6° isotherm at 25 metres and the 9° surface isotherm were in approximately the same positions in much of the area. Between St. Lawrence Island and the Siberian mainland, values below O° C. were found at 25 metres. The isotherms for 25 metre depths are shown in Figures 1 and 6 and for the surface in Figure 4.

In integrating the study, we see that in general the distribution of zooplankton is closely associated with the hydrographic conditions. Thus, also, biologically the area, even in the narrow portion of Bering Strait, can be roughly divided into a western and an eastern section, each with its characteristic community with respect to presence or concentration of either neritic or offshore forms. The eastern neritic community extends westward to include the Pribilof Islands where local production is apparently favoured by the tongue of warm water that enters into the general area. Along the north side of the Aleutian Islands the picture is somewhat confused. The flow of water from the deeper areas permits of no considerable concentration of strictly neritic forms except in the immediate vicinity of the Aleutian Islands and we find an admixture of the relatively more deep water, open sea forms *Calanus tonsus, Metridia lucens,* and *Eucalanus bungii.*

Unfortunately, no 1934 net samples are available for the stations midway between St. Paul and Nunivak Islands, but at the latter island there was present a typical inshore community, with a large number of temporary pelagic larvae of echinoderms and annelids, and such pelagic copepods as *Tortanus discaudatus,* and *Epilabidocera amphitrites.* This community persists along the Alaskan coast. Westward from Nunivak Island, however, the neritic element dropped off sharply before reaching the cold waters around St. Matthew Island. At that island was found a very sparse plankton population of a few forms more or less common to both areas, but none of the species common on the Alaskan coast were taken. Here, too, the hydrography offers a probable explanation. St. Matthew Island occupies a position nearly as favourable as the Pribilof Islands with respect to distance from shores producing a strong neritic plankton community, and with respect to surrounding area of shoal water. The critical difference appears to be associated with the direction of prevailing currents and source of water bathing the islands. At St. Matthew Island the currents bring cold water from the west, and probably tend to carry away much of the local production, without replacing it with an incoming supply. The whole section from St. Matthew to St. Lawrence Island was also a barren one at the season of sampling. The plankton community occurring between St. Lawrence Island and Siberia, and along the Siberian side of Bering Strait included the same offshore copepods as were found between the Aleutian Islands and the Pribilofs (Figures 1 and 4). The areas off the Siberian coast are supplied with cold water flowing from the deeper more open sea lying to the south-west.

Some of the coastal community forms may be dispersed by the northward set of the current through Bering Strait along the Alaskan coast, and, thus, reach latitudes unusually high for the species. This is illustrated by the northward extension of *Eucalanus bungii* and *Acartia clausii,* and possibly *Epilabidocera amphitrites,* and others.

The zooplankton distribution indicated by these surveys portrays only the conditions at the prevailing August temperatures. Higher temperatures over a wider area would doubtless favour a wider production and distribution of the neritic forms, for the salinities appear to be favourable over much of the area where depths are relatively shallow.

Sewell (1948) is of the opinion that Arctic species are carried southward through the Bering Strait, but there is no evidence of this during the summer months when the currents appear to flow persistently northward through the Bering Strait.

For a full understanding of the direction of dispersal of the Boreal-Arctic species of the Pacific it will be necessary to have more detailed information on the direction of flow of water through the Bering Strait, especially during seasons other than summer.

SUMMARY

1. Analysis was made of net plankton from 102 stations occupied in 1934, and 21 occupied in 1947, extending from the Aleutian Islands into the Arctic to the edge of the ice pack.
2. Hydrographic observations during the summer reveal the presence of relatively dilute warm water in the eastern section of the Bering Sea and Bering Strait. Along the Alaskan coast the current has a northerly set, and the same is true along the Siberian coast. The flow is stronger and the waters are colder and more saline on the Siberian side of the Bering Strait.
3. Correlated with the hydrographical features, the zooplankton study indicates (1) a western community, characterized by offshore deep-water species, such as *Calanus tonsus, Calanus crista-*

tus, *Eucalanus bungii bungii*, and *Metridia lucens*, and by a relative absence of temporary plankton; and (2) an eastern neritic community, characterized by neritic or estuarine forms, such as *Tortanus discaudatus*, *Epilabidocera amphitrites*, *Eurytemora herdmani* and temporary larval stages of littoral invertebrates.

4. The offshore community extends somewhat eastward just north of the Aleutian Islands, and northward through the Bering Strait on the Siberian side.
5. The neritic community includes the Pribilofs and Nunivak Island, and the coast of Alaska. Alaskan neritic forms are apparently carried through Bering Strait along the eastern side, and thus may reach latitudes usually high for the species. The more offshore forms are carried into the Arctic through the western part of the Strait.
6. The large numbers of larvae of benthic animals, especially echinoderms, lamellibranchs, and barnacles gave evidence of abundant spawning in mid-summer clear up into the Arctic Ocean.

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Discussion

Professor Yonge stated that the capture of larvae, but not the adult forms, was quite usual, even in places so thoroughly investigated as Plymouth, e.g. many *Squilla* larvae had been taken, but adults were very rare. He asked Dr. Johnson whether any molluscan larvae had been collected. Dr. Johnson in reply said that pelecypod larvae were concentrated in a line from Alaska past St. Lawrence Island to the Siberian coast. Distribution of these larvae did not conform to that of other larvae taken. It was of interest that the walrus comes down past St. Lawrence Island, indicating that there are probably many bivalves in this area. Professor Yonge said that bivalves near Greenland nearly all have a direct development and provide another example that the proportion of directly developing forms becomes higher in the higher latitudes. Miss Allen asked if any larval squids were taken. Dr. Johnson replied that none were found, but sampling was not satisfactory for swimming forms, e.g. few Euphausiids were captured, although they must have been present. Dr. Hubbs said that the sampling given in this paper was made during a period of ameliorated climate. The conditions were probably different when ice used to come down to the Pribilof Islands. Apparently there is now a northward movement of plankton which may not have occurred at that time. He suggested that the salmon, lamprey, and other forms may also now go further north. Miss Pope asked if the genera of barnacles had been determined. Dr. Johnson replied this had not yet been completed. Professor Yonge asked the depth of attachment of the barnacles. Dr. Johnson stated that this was approximately 30-40 metres. Dr. Hubbs mentioned that on the West Coast they were much deeper.

A VIEW OF NEW ZEALAND FISHERIES

By L. R. Richardson, Victoria University College, Wellington

The New Zealand fisheries present a picture which is unfortunate in a time when actual and potential food-shortage threatens the welfare of so many peoples. In spite of our oceanic position, this country neither supplies itself adequately with marine products, nor contributes to world markets. This position can best be understood in the history of the community. These shores were too remote even for the voyaging fishermen who established strong fisheries in the more accessible parts of the world. The settlement of this country was abrupt. Attention was directed to timber and the land. It must be realized that the fisheries of this area have been left for a hundred years in the hands of a community which is independent of the sea, seeks its living from the land, and finds its international trade in produce from the land. The marine resources of New Zealand are not, and have not been held in general view as a tangible national asset capable of supplying the needs of this nation and capable of a significant contribution to the feeding of the world.

The development which has taken place has until recently been essentially for the supply of fresh sea-foods to markets in the immediate vicinity of the major and minor ports. Little attention was given to the supply of more remote districts, and the general pattern was more that of a mediaeval coastal fishery than of a modern economic industry seeking the maximum and proper utilization of the available resources. The lack of a profound community interest in national fisheries is reflected in the limited utilization of fish as a food by the New Zealand community. Home-cooked fish plays a minor role in the diet of the majority, and the general demand is for the commercially prepared product—some ten years ago, imports of processed fish and other sea-foods approached 10 per cent in weight of the landings of wet fish; and about 9 per cent in 1947. The utilization of fresh fish is remarkably limited. Nearly 50 per cent of the landed catch consists of only two species.

The total landings of wet fish for 1947 amounted to 438,300 cwt. brought into 57 ports. Of this catch, one port landed over 100,000 cwt.; two ports over 40,000 cwt.; and two ports landed between 20,000 and 30,000 cwt. each. In brief, five ports landed some two-thirds of the catch. This is of course merely an expression of the concentration of the fishing fleet. Some 800 licensed vessels are operating, and superficially it would seem that a fleet of this size represents a reasonable industry for our community; but the figure of only 1,500 men employed shows that the fleet contains a very high percentage of small craft and that much of our fishing endeavour is concentrated in inshore waters in the immediate vicinity of home ports. The fleet includes only 12 steam trawlers and 44 motor seine boats which collectively land about one-half of the catch. In other words, 52 of our ports depend essentially on small craft and collectively land only one-third of the total catch.

This part of the picture is reasonably clear. There is a general lack of small highly productive communities dependent upon fishing as a primary source of livelihood. The production and efficiency of the bulk of our minor ports is far below a reasonable level.

To set this aspect in proper perspective, it must be realized that for our population and area, this country possesses an extremely long coast-line. The general coast-line of the two main islands is at least 3,000 miles in length, more than double the general coast-line of the Pacific side of the United States. In addition, it must be understood that New Zealand does not rise from the depths of the sea like a razor-edge, but has at least as great an area of continental shelf, as it has of fertile lowland country. None would limit the productivity of our lowlands at the level of our present fisheries production, but there is an acute timidity hindering fisheries development. This timidity, the fear for the exploitation and destruction of our marine resources, is largely based on a faulty appreciation of the extent and fertility of our seas. Few appreciate that the fertility of the shallow sea and its capacity for the production of protein approaches close to that of the average production from the land in most countries.

There is need for the creation around our coasts of small but efficient minor fishing ports concentrating on the supply of smoked, dried and canned products for the New Zealand and overseas market. There is no real lack of harbours. Frequent and violent storms, the high cost of equipment and labour are surmountable difficulties which would be overcome if our economic dependence on marine resources was greater.

The potential development of our fisheries resources cannot be closely estimated. The catch of wet fish has exceeded 400,000 cwt. for the first time, a figure which is still absurdly small in relation to the area and extent of the waters suitable for the maintenance of fish. Increased attention to the catch of a wider range of species should at least double our landings and by calling upon essentially untapped resources should in no way harm our fisheries in the future.

There are certainly remarkable opportunities for increase of the spiny crayfish catch. Crayfish are at present landed at 32 ports, but landing at these ports was in excess of 1,000 cwt. at only seven ports which together received three-quarters of the 16,766 cwt. landed in 1946, a figure which rose to only 18,052 cwt. in 1947. In the very nature of this fishery, it is clear that a three-fold and greater expansion of the catch is possible, and would be made if the community in general appreciated its responsibility as much in the development of our marine as our terrestrial resources. It is wrong that we permit many hundreds of tons of crayfish to waste in the sea when this commodity is eagerly sought by other people. Our export of crayfish has never exceeded a token quantity. Equally we might develop a prawn fishery, for from the evidence of fish stomachs it is clear that a commercially desirable prawn is present in considerable quantities at some parts of the coast. So far as I am aware, it has never been fished, although in past years this country imported many hundredweight of prawns each year.

In contrast to the wet-fish and crayfish, our shell-fish industry has been an active one. Rock and deep-water oysters are taken in reasonable quantities and marketed both fresh and canned. Mussels have had a fair market. The toheroa is the basis of a limited canned "clam" fishery. Recent years have seen the development of a paua (*Haliotis*) fishery with some 20,000 at least taken for meat. Our knowledge of the possibilities in the further development of these and kindred fisheries is still inadequate, but certainly the rock-oyster offers an excellent possibility for intensive and extensive cultivation.

We have then in this country an example of economic waste in the international sense. New Zealand has domain over an extensive stretch of sea but since the resources of the sea are not storable, are underutilized and much is lost each year, our fishery is an interesting contrast to our agricultural production. The New Zealander is acutely aware of the position of his country as a source of dairy goods, meat and wool for the people of the world; but he has no vision of the national responsibility with regard to the sea.

There is a hampering lack of a vigorous national policy for the proper utilization of the marine resources of this country. Without a fishing tradition in the first place, the New Zealander turned his back on the sea and devoted himself to the land. The lack of national policy stems from the community as a whole and can be countered only by the education of the New Zealander to an appreciation of the true economic value of the seas and of the need for the full development of our fisheries. In the absence of a tradition rooted in the community it may be many years before such development can take place, and at this time we might well consider that the establishment of an international agency might provide the only ready and proper development of our fisheries. It is an interesting possibility, that a major organization with wide experience and skill might take over our fisheries in part or whole and develop them to their full extent in terms of the needs of the peoples of the world.

Discussion

Professor Yonge asked if there was much excess in the quantity of fish available. In reply Professor Richardson cited crayfish which come ashore at certain times in very great numbers. He also referred to a two-year study of the tarakihi, showing no trace of over-fishing.

Mr. Hobbs remarked upon some of the practical difficulties which should be considered before a criticism be directed at the methods of exploitation of fish in New Zealand. The superabundance of cheap mutton made the prices of fish highly competitive. There were limited possibilities of increasing local consumption by qualitative improvement in the handling of and presentation of fish to the public. Although Professor Richardson had stressed and criticized the extent of imports of canned fish, actually these were of equivalent value to, and of smaller quantity than, her exports of frozen fish to Australia. Even the existing export trade was hampered greatly by shipping difficulties, which were severe enough between here and Australia and would be greater if more extended exports were sought. A further bottleneck was refrigerated storage space—at present used to full capacity and incapable of being immediately increased. While there were some lightly exploited inshore waters, internal transport difficulties usually made collection of intermittent landings from small second-grade ports uneconomic. As regards crayfish, he was under the impression that where increased exploitation had been attempted for canning, on some sections of coast depletion had rapidly followed and the industry had collapsed.

Mr. Cassie suggested that the views expressed by the speaker were over-optimistic as to the inexhaustibility of demersal fish stocks. He pointed out that some of the main trawling grounds were showing serious signs of depletion, notably in the Hauraki Gulf, where fish is now so poor that trawlers and seiners have been forced to operate further afield in the Bay of Plenty and East Cape regions. The operation of even the smallest fishing communities must, of necessity, be limited to places where suitable harbours were available. Almost every sheltered port in New Zealand had a fishing fleet of some kind, and coverage of the coast-line was fairly complete, with the exception of some part of the west coast of the North Island, where safe anchorages were lacking, and weather conditions sometimes dangerous for even the larger craft. The fact that over 50 per cent of the catch consisted of two species only might possibly be explained on the grounds that these two did indeed comprise about half the fish population of the grounds in use. He expressed the opinion that uncontrolled exploitation would have a disastrous effect on the present demersal fishery. At the same time better use might be made of available stocks, by refinement of present methods of handling, and by education of the public as to the palatability of certain species not always favoured at present. Any hope for a large-scale expansion of New Zealand fisheries could rest only on the taking either of pelagic fish, or of demersal fish from the waters beyond the continental shelf, an expensive undertaking, the success of which could not be forecast in the light of present knowledge.

Dr. R. C. Miller pointed out that New Zealand was the logical headquarters for the exploitation of a vast sector of the Pacific Ocean. Thus, although for domestic purposes New Zealand fisheries might be limited, on an international scale a great potential oceanic fishery extended to the eastward. He suggested that if, as Professor Richardson had suggested, competent fishermen were lacking in New Zealand, such men might be recruited from the Mediterranean and north-eastern Europe.

Professor Yonge, in summing up, stressed that local consumption was much conditioned by the abundance of cheap meat, that there were practical difficulties of increasing export, that there were serious reservations as to whether demersal fisheries would stand up to greatly increased exploitation, and he emphasized the need for more knowledge as to the extent of the continental shelf and also of the extent of pelagic resources.

BIOLOGY OF THE MARINE SPINY CRAYFISH *JASUS LALANDII* (MILNE-EDWARDS) IN NEW ZEALAND WATERS

By C. A. Bradstock, Victoria University College, Wellington

The marine crayfish is of considerable economic importance in New Zealand. In 1946, 16,766 hundredweight (valued at £30,801) was marketed. Exports of frozen and canned crayfish were valued at £11,704. More crayfish are landed at Wellington than at any other port in New Zealand.

Although considerable work has been done on this species in South Africa and Australia, little has been done in New Zealand. These notes summarize some of the conclusions of a study of 2,126 specimens carried out during 1947 and 1948 under a grant from the Marine Department (to be published as Fisheries Bulletin No. 11).

In Wellington waters, fishing is carried out mainly inshore on the rocky parts of the coast, but trawlers occasionally take large catches in the trawl nets in deeper water. There is considerable variation in the size of the catches throughout the year, the heaviest catches being taken in September when large males appear in considerable numbers.

No crayfish smaller than 17 cms. in total length (tip of rostral spine to end of telson) are caught. The smallest size caught is not determined by the size of the mesh used so that crayfish smaller than 17 cms. must either be absent from the fishing grounds or are not attracted by the bait. The largest female found was 32 cms. and the largest male was 40 cms., which indicates that males reach a greater size than females.

The size of males most frequently caught varies from month to month. A large number of very large males is taken in September which leads to the conclusion that large males, absent from the fishing grounds at any other time, move inshore in September. Few large males are taken in October which indicates that their stay inshore is very temporary. The size range of females most often caught does not vary greatly so that the female population appears to be fairly stable.

The ratio of the sexes in the catches varies considerably from month to month. Females predominate in the December, January and February catches. This is probably due to moulting in males. The percentage of females in May is small, probably as a result of moulting and egg-extrusion. In April, so few crayfish may be obtained that fishing is not worthwhile. This also is probably a consequence of moulting, copulation and egg-extrusion in females and copulation in males. In June, July and August there are approximately equal numbers of males and females caught. In September, the proportion of males increases, probably as a result of an inshore movement of large males as suggested above. Another possible contributing factor is an inactive condition of females just before and during larval-release. In October, when larval-release is complete in many specimens, females appear in large numbers and, in November, when larval release is complete in almost all of the females, and when males are beginning to moult, females are present in even larger proportion. In December, when all females have finished larval-release, and when males are moulting, females predominate in the catches.

The present legal size limit of 9 inches (22·9 cms.) in total length appears to be reasonably suitable for the following reasons. Firstly, some females become mature when about 7½ inches (19·1 cms.) in total length and all are mature when they reach 10 inches (25·4 cms.) so that the present restriction, although not protecting all of the immature specimens, does protect most. Secondly, leg meat is so difficult to extract from specimens smaller than about 9 inches that it is used by few people, if any. The leg meat of crayfish slightly larger than 9 inches can be readily extracted and comprises one-third of the usable meat. Small crayfish have relatively less tail meat than larger ones. Accordingly, it is wasteful to take crayfish smaller than about 9 inches in total length. Thirdly, under the 9-inch limit, the fisherman has to reject only 8 per cent by weight of the catch which is not a very great hardship. It must be noted, however, that raising the limit another inch would necessitate the rejection of 15 per cent of the catch.

The limited results of tagging operations indicate that there is no purposive migration but merely a haphazard movement of the type to be expected from random wandering in search of food.

Tagging work has given limited data on growth rate. A male, 21·5 cms. in total length when released, grew 2·1 cms. in total length in one year. A female, 24·8 cms. in total length when released grew 1·9 cms. in total length in the same time. There is evidence to indicate that specimens of about this size moult twice in one year so that the average growth per moult, in specimens of this size, is about 1 cm. in total length.

All females are "in berry" in May and it is probable that egg-extrusion begins in April. Most of the females release larvae in October but a few are still found "in berry" in December. All are free of eggs by the end of December. Larval-release may be correlated with the period of increasing temperature which begins in late August. There is evidence to indicate that large females extrude their eggs before small ones.

The number of eggs produced increases approximately as the cube of the length of the body. For the size range 8·3 cms. to 13·5 cms. carapace length the number of eggs ranges from 86,000 to 549,000.

The amount of usable meat ranges from 47 grams in the smallest (6·7 cms. carapace length) to 1,449 grams in the largest 19·6 cms. carapace length). The weight of usable meat per unit carapace length ranges from 6·7 grams to 74 grams over the same size range.

Discussion

Professor Richardson compared research on crayfish in Australia, Tasmania and South Africa. The New Zealand catches of crayfish differed from those discussed in these papers in that there was a change in sex ratio of crayfish in New Zealand waters.

SUR LA COLLECTION DES STOMATOPODES DE L'INSTITUT OCEANOGRAPHIQUE DE L'INDOCHINE

Par R. Serene, Institut Océanographique de l'Indochine

Le groupe des Stomatopodes appartient surtout à la zône Indo-Pacifique. La principale monographic de ce groupe a été établie par Kemp (1913) en partant de l'étude de la collection de Stomatopodes de l'Indian Museum de Calcutta. Sur 139 espèces et variétés alors connues, 97 appartenaient à la Région Indo-Pacifique pour 42 au reste du monde. Depuis 1913, on n'a décrit que 40 espèces et variétés nouvelles dont plus de 30 de la zône Indo-Pacifique.

En Indochine, Gravier, dans plusieurs publications (1930-1933-1937) avait signalé déjà 16 espèces; par une prospection systématique des sites de récolte des Stomatopodes d'Indochine, j'ai trouvé 27 espèces dont 11 pas encore signalées en Indochine. Ces récoltes constituent la collection actuelle de l'Institut Océanographique de l'Indochine (1.286 spécimens). Parmi ces espèces, plusieurs sont rares, leur diagnose étant, de ce fait, souvent imprécise. Certaines connues seulement à ce jour par 5 ou 6 spécimens ont été trouvées en plusieurs exemplaires et leur étude détaillée est actuellement en cours.

Je signale toutefois que, malgré une prospection méthodique, *Squilla latreilli*, *Squilla costata*, *Squilla multicarinata*, *Odontodactylus cultrifer*, *Odontodactylus carinifer*, *Gonodactylus acutirostris*, *Gonodactylus demani*, *Gonodactylus brooksii* restent rares au regard d'espèces comme *Squilla nepa* ou *Squilla wood-masoni* dont on peut recueillir des milliers d'exemplaires. Au contraire, *Gonodactylus glaber* et *Gonodactylus glyptocercus* qui pouvaient, jusqu 'à ce jour, être considérés comme rares sont très fréquent à Nhatrang.

Le tableau ci-dessous des espèces de la collection de l'Institut Océanographique de l'Indochine avec le nombre d'échantillons ne donne le nombre des spécimens signalés par les auteurs que pour les espèces rares.

COLLECTION DES STOMATOPODES DE L'I.O.I.

No-d'ordre	Noms des ESPECES		Signalés en Indochine	Nombre des spécimens connus à ce jour	Nombre des spécimens de l'I.O.I.
1	*Squilla latreilli*, Eyd. & Soul.	1841	Gravier 1937	13	15
2	*Squilla fasciata*, de Haan	1844	Gravier 1930 & 1937	22	130
3	*Squilla nepa*, Latreille	1825	Gravier 1937	+	150
4	*Squilla holoschista*, Kemp	1911	Gravier 1937	+	2
5	*Squilla oratoria*, de Haan	1844	Gravier 1930 & 1937	+	171
6	*Squilla wood-masoni*, Kemp	1911	Non signalé encore.	72	204
7	*Squilla massavensis*, Kossmann	1880	Non signalé encore.	16	17
8	*Squilla costata*, de Haan	1844	Gravier 1933	6	8
9	*Squilla multicarinata*, White	1847	Serène 1939	12	7
10	*Squilla raphidea*, Fabricius	1798	Gravier 1930	+	114
11	*Pseudosquilla ciliata*, Fabricius	1787	Gravier 1937	+	16
12	*Pseudosquilla ornata*, Miers	1880	Non signalé encore.	+	7
13	*Lysiosquilla maculata*, Fabricius	1793	Gravier 1937	+	16
14	*Lysiosquilla acanthocarpus*, Miers	1880	Serène 1939	+	1
15	*Odontodactylus scyllarus*, Linné	1767	Gravier 1937	+	4
16	*Odontodactylus carinifer*, Pocock	1893	Gravier 1933	3	9
17	*Odontodactylus cultrifer*, White	1850	Non signalé encore.	5	3
18	*Gonodactylus chiragra*, Fabricius	1781	Gravier 1933 & 1937	+	200
19	*Gonodactylus acutirostris* de Man	1898	Gravier 1937	2	15
20	*Gonodactylus demani*, Henderson	1893	Non signalé encore.	30	9
21	*Gonodactylus glabrous*, Brooks	1886	Gravier 1933	+	9
22	*Gonodactylus glaber*, Lenz	1905	Gravier 1937	8	55
23	*Gonodactylus, pulchellus*, Miers	1880	Gravier 1937	+	4
24	*Gonodactylus excavatus*, Miers	1880	Gravier 1937	+	3
25	*Gonodactylus glytocercus*, Wood-M.	1875	Non signalé encore.	30	100
26	*Gonodactylus brooksii*, de Man	1888	Serène 1947	4	16
27	*Gonodactylus spinosissimus*, Pfeff.	1888	Serène 1939	20	1
					1286

DISCUSSION

Dr. Hiatt asked if any work had been carried out on the development of Stomatopoda in Indo-China. Dr. Serene said they had been led to the study of adults by the difficulty of classifying larvae of which more than a thousand catches had been made either as plankton catches or by line fishing. At present it is not possible to study the larvae by reference to the adult forms. Work on development of the Stomatopoda had been carried on both in Japan and at Bangalore. Up to the first post-larval stage, the development has been fairly adequately studied, but owing to the numerous metamorphoses, the

pelagic stages are not well known, and insufficient numbers have been reared to be sure of the stages during development.

Dr. Serene remarked that in the study of these collections he attached a good deal of importance to the colouring of the living specimens.

PREMIERE LISTE DE POISSONS COLLECTES EN NOUVELLE-CALEDONIE

Par M. Legand, Institut Français d'Océanie, Noumea

[*Résumé*]

Depuis sa création, en Janvier 1948, le Laboratorie d'Océanographie a collecté plus de 80 espèces de poissons. La présente communication donne les noms de 80 espèces déterminées avec certitude.

PREMIERE CONTRIBUTION A L'ETUDE DU GENRE *STOLEPHORUS* LACEPEDE (CLUPEIDAE) EN NOUVELLE-CALEDONIE

Par M. Legand, Institut Français d'Océanie, Noumea

[*Résumé*]

Au cours de recherches ichthyologiques, deux types du genre *Stolephorus* ont été trouvés dans la même station. Une étude biometrique de croissance a été établie. Il en résulte pour plusieurs caractères, et en particulier pour la longueur du maxillaire, des courbes distinctes et de pentes très différentes. Ces deux types peuvent être rattachés, l'un à *Stolephorus tri* Bl., l'autre à *Stolephorus indicus* v. Hass. Le caractère discriminatif le plus simple à employer est le rapport $\frac{M\ x}{H} > 1$ pour la première espèce et < 1 pour la seconde. La différence de pente des courbes peut toutefois faire penser à un dimorphisme sexuel.

THE ACCLIMATIZATION OF THE PACIFIC OYSTER (*OSTREA LAPEROUSII* SCHRENCK = *OSTREA GIGAS* THUNBERG) UPON THE WEST COAST OF NORTH AMERICA

By Trevor Kincaid, Department of Fisheries, State of Washington

The development of the present oyster industry of the Pacific coast of North America traces back to prehistoric times. When the white man encountered the aboriginal tribes of Indians inhabiting the coastal areas of what are now the Province of British Columbia and the States of Washington and Oregon, they found the natives utilizing for food the small indigenous oyster *Ostrea lurida*. Later, through the discovery of extensive kitchen-middens composed largely of the shells of this species, it was surmised that the use of this mollusc by the aborigines must date back over a great period of time.

During the early settlement of the region in the middle of the nineteenth century, the white people depended largely upon the Indians to bring in supplies of oysters in exchange for other commodities. As the population of the pioneer communities became greater and means of transportation improved, the demand increased, and as a result an industry was established under the control of the whites, but employing Indians to perform the necessary labour upon the beds. Later on a number of Chinese were employed, and eventually these were replaced by Japanese who, up to the outbreak of hostilities in the Pacific, held almost a monopoly of the labour employed in the various operations involved in the cultivation and processing of the small native oyster.

Unfortunately the unrestricted utilization of the indigenous species resulted in a depletion, which eventually caused the destruction of a number of the original producing areas, and reduced others to a state bordering on extinction. In a few of the more important centres, more especially in the group of bays radiating from the southern extremity of Puget Sound, an attempt was made, with excellent results, to restore the beds to a high state of production. By means of costly engineering, extensive areas of the inter-tidal flats were covered with structures similar to the "claires" utilized by the French oyster-culturists, but which were submerged at each tidal movement. In these shallow basins, walled in by low concrete dikes, it was found the oysters throve and reproduced, so that the depletion was not only arrested but the supply of oysters was gradually increased. In spite of setbacks due to pollution and the introduction of dangerous predators and parasites from abroad this branch of the industry has remained in a flourishing state, although restricted in scope through lack of suitable tide-flats on which to conduct this highly specialized type of oyster culture.

The demand for a larger species of oyster designed to satisfy the taste of those accustomed to the variety cultivated upon the Atlantic coast, led to an attempt to acclimatize this species in the shallow waters of the western states, but this having failed after extensive and costly experiments, those interested in the industry cast about for some substitute. It was of course generally known through the reports of Bashford Dean and others, that an industry of considerable magnitude had been developed by the Japanese upon their coast, and it was also known that an unusually large variety of oyster, classified at the time as *Ostrea gigas,* had been discovered by the Japanese in some of the bays on the northern island of Hokkaido, and that it was being brought under tillage by them in a group of bays located on the coast of the province of Sendai, about one hundred and fifty miles north of Tokyo. As to the proper systematic designation of this species, recent investigation indicates that the specific name *gigas* was preoccupied, and as a result the current name of the species must be changed to *Ostrea laperousii.* From time to time contacts were made with representatives of the Japanese oyster-growers, and sporadic efforts were made to bring over some of the molluscs for experimental planting. The earlier shipments were composed almost exclusively of adult oysters for rebedding, but a variety of experiments demonstrated that quite young oysters, even those less than a year old, could be safely shipped in wooden boxes with a capacity of about two bushels, if carried as a deckload on ships travelling by the cool northern route across the Pacific, skirting the Aleutian chain.

The first consistent attempt to establish the Japanese oyster in our waters on a commercial scale was made by a group of Japanese who in 1905 formed a company for this purpose. They secured possession of a tract of tide-flats located in Samish Bay, about fifteen miles south of the city of Bellingham. A considerable quantity of oysters, both mature and immature, were brought over on an experimental basis. The animals were found to mature rapidly and produced a crop of oysters that were of first class quality, but the Japanese company encountered great difficulty in marketing their crop because of a strong anti-Japanese movement which existed at the time, and in addition the Legislature of the State of Washington passed an anti-alien landholding bill which clouded the title of the Japanese and made it difficult for them to transact business. As a result the Japanese company sold their holdings to a group of white oyster-men who formed a corporation for this purpose.

The new company also at first encountered great difficulty in marketing their product, partly because of its Oriental origin, and partly through the natural prejudice which one encounters in introducing a new type of food material to the public. In due time this prejudice was broken down, partly by coining the trade name of "Pacific Oyster" for the Japanese species, and the market was rapidly expanded as more extensive plantings were laid down and larger quantities of the mature oysters became available. At the same time the production of seed oysters on the coast of Japan was increased. Likewise new plantings were made at several other points on the coast where suitable tide-flats were available. Among these was Willapa Bay, an extensive body of shallow water on the south-western coast of Washington. This area had originally been the seat of an extensive industry based upon the native oyster, but had suffered depletion and the land was lying idle. The first planting of Pacific oysters in this area was made in the year 1928 and consisted of 40 cases of seed, equivalent to 80 bushels. This was followed in 1929 by a planting of approximately 3,000 cases, which initiated a development which was destined to place this bay in the lead as the main centre for the commercial production of the Pacific species. Plantings were soon made in some of the bays in British Columbia, followed by others on the coast of Oregon and California. A few plantings have even been made in south-eastern Alaska. As a result the industry has undergone a remarkably rapid expansion, and in spite of a setback during the war, which cut off the importation of seed for several years, the annual production has now reached a point where the yield to growers and processors amounts to more than six million dollars per annum, while the distribution is nationwide.

In the early stages of the development of the industry, the product was marketed almost exclusively in the form of shucked oysters, but it was soon found that a canned product of excellent quality could be produced. This initiated the steam pack branch of the industry, which rapidly overshadowed the shucked oyster trade. More recently other lines of production have been developed, especially the smoked oyster branch, which has already assumed an important place in the gross production. Considerable quantities of a very palatable canned oyster soup have also been placed before the public.

In addition to the bodies of the animals themselves the oysters yield as one of the by-products of the industry great quantities of shells, which are utilized on a large scale as cultch in securing a set of young oysters. The shells are also processed by shell-grinding plants for the production of chicken grit and fertilizer. It is proposed to use this material for the making of lime for special purposes. No doubt other uses will be found for the shells.

Soon after the original plantings of Pacific oysters were established in Willapa Bay it was observed that the animals were beginning to reproduce, especially in unusually warm summers when the waters attained sufficiently high temperatures to precipitate spawning, which occurs at about 20° C. On several other areas, notably in Hood Canal, a similar phenomenon was observed, and as the oyster population increased the spawning activities of the animals became more effective. It was hoped that in time the natural propagation of the oysters might ensure a supply of seed from local sources, and thus obviate the dependence of the industry upon the Orient for its supply of raw materials in the form of oyster seed. Another objective was to lessen the danger of importing dangerous predators and parasites in addition to those already present. However, although it has been found that in favourable seasons reproduction is apt to occur in both Willapa Bay and Hood Canal, several years may go by in which the meteorological conditions are unfavourable and spawning fails to take place. This leads to a measure of uncertainty, which has caused the growers to retain their original connection with the Japanese seed producers, not only to tide over unfavourable seasons on the American side, but also to provide a supply of seed for areas where the waters are too cold for the oysters to spawn. The possibility of raising seed in reservoirs under controlled conditions has also been given consideration.

The methods employed by the American oystermen to secure spat were adapted from the Japanese technique. Wooden trellises are built upon the flats in the inter-tidal zone, and upon these, strings of shells attached to wires are suspended in such fashion that the swimming larvae of the oyster will contact the exposed surfaces and become attached to form young oysters. After the spat have reached a stage where they can withstand transportation the shells are removed from the trellises and broadcast upon ground selected for growing purposes. A year or so later the clusters of young oysters which have grown out from the cultch shell are broken up and the resulting material broadcast once more, to remain on the growing ground till the animals attain a marketable size, which is ordinarily in their third year. Loose shell is also frequently broadcast upon selected areas for spatting purposes, but the recovery of this material for rebedding is not so convenient as in the case of the strung shell.

Owing to the manner in which the seed oysters are shipped from Japan to our Pacific coast, enclosed in wooden boxes holding approximately two bushels, many other animals have been able to survive the trans-Pacific journey and thus arrive in a living state, and like the oysters make themselves at home upon the flats. A few of these stowaways have proved to be desirable additions to our fauna, as in the case of the clam *Paphia philippinarum,* known to the Japanese as Asari, which has thrived upon the gravelly beaches of Puget Sound and Willapa Bay, and is now coming into the local markets in increasingly large quantities. In most areas it seems to be displacing the native species *Paphia staminea.* Some of the immigrants, including a few gasteropods, would seem to be quite innocuous, although their impact upon the native fauna is quite apparent. Included, however in the invading organisms are some that have proved to be highly injurious, not only to the Pacific oyster which they accompanied but even more so to the smaller, less well protected, native oyster *Ostrea lurida*. Chief among these is the Japanese drill, *Tritonalia japonica*, a gastropod which has turned out to be a most destructive pest, causing the death of large numbers of oysters in the areas to which it has penetrated. Fortunately it has not yet appeared in Willapa Bay, and with the aid of the excellent inspection service which has been placed in operation it is to be hoped it may be permanently excluded. Another pest which at times has caused considerable concern is the curious parasitic copepod *Mytilicola orientalis*, which infests the alimentary canal of the oyster and other bivalves. While this species rarely causes the death of its host it reduces the vitality of the animals, and it also becomes a nuisance when it appears among the shucked oysters, since its reddish colour makes it quite conspicuous. A third organism which causes considerable damage to the oyster is a species of annelid of uncertain origin belonging to the genus *Polydora*. It burrows into the valves of the mollusc, which becomes deformed when the oyster attempts to protect itself from invasion by cutting off the injured spot by a deposit of nacre. The fact that injury of this type seems to have been unknown in the bay previous to the introduction of the Pacific oyster points to the probability that it is a foreign species. Material from Japan has not yet been available for comparison. In all probability a great many other marine organisms, especially those of microscopic size that can survive in the spore state, may have come in as well, and in due time may modify the biota of the bays into which they have been introduced. In addition to the pests introduced from Japan several injurious forms have been brought over from the Atlantic coast, including the ubiquitous slipper shell *Crepidula fornicata* and the common oyster drill.

The harvesting of the Pacific oyster is accomplished partly by direct hand labour, the animals being loaded on scows that are brought to rest upon the flats with the receding tide, but increasing reliance is being placed upon mechanical means of gathering the crop. Power dredges similar to those employed upon the Atlantic coast are coming into general use, while a powerful suction dredge, capable of removing great quantities of oysters from the ground in a very short time, is being utilized.

The economic and social results of the introduction of *Ostrea laperousii* into the embayments of our Pacific coast have been rather far-reaching. At the time the importations were initiated, the bulk of the inter-tidal flats were almost devoid of commercial utilization, and in some cases, as in Willapa Bay, the decadence of the industry based upon the native oyster caused most of the tracts to revert to the state for non-payment of taxes, and this in turn caused the deterioration of the communities which had relied upon the oyster industry for their economic stability. The reorganization of the industry upon a new and more sustained basis has not only built up a local payroll but it has also stimulated many other collateral businesses, such as boat building, iron working, transportation, etc. From the standpoint of the national economy the development of the industry based upon the Pacific oyster has brought under tillage large areas of otherwise idle land, and introduced to the consuming public an abundant and wholesome supply of food material, recognized as being not only palatable and nutritious, but also as containing a remarkable content of vitamins and minerals highly desirable in the bodily economy.

THE DEVELOPMENT OF THE DOGFISH FISHERY IN BRITISH COLUMBIA

By W. E. Barraclough, Pacific Biological Station, Fisheries Research Board of Canada, Nanaimo, B.C.

The dogfish (*Squalus suckleyi* Girard) is a small shark reaching a length of slightly over five feet. It belongs to the family Squalidae and is found in abundance in the waters off the British Columbia coast. The range of this species is from southern California to north-western Alaska.

Oil extracted from the livers of the dogfish was one of the earliest products of the fishing industry in British Columbia. Lord (1866) noted that the Pacific Coast Indians extracted the clear oil from the fatty livers by heat and pressure for their domestic uses. In some instances extraction of the oil from the carcasses was attempted in a very primitive fashion. After cleaning the fish, they would cut them into pieces, boil them in vats, place them in large tubs, and the women would press the oil out by trampling with their feet. This made a very inferior oil which was mostly used for dressing skins, and for greasing skidways on logging roads (Mowat, 1888). The production of dogfish liver oil gave employment to a large number of persons along the seaboard of the province, opening a valuable industry to both the native fisherman and the European. Large quantities of oil were consumed for lubricating and lighting purposes in the extensive sawmills at Burrard Inlet, in the coalmines at Nanaimo and Departure Bay, and by numerous steamers and sailing vessels frequenting these waters (Anderson, 1877). Two of the light stations on this coast burned dogfish oil exclusively. The oil was claimed to give a luminous and brilliant light and, besides, was cheaper than any other oil that could be imported during this period (Cooper, 1874).

During the spring of 1877 an establishment employing white fishermen was formed on the Queen Charlotte Islands for collecting dogfish oil (Anderson, 1878) and two years later the Skidegate Oil Company largely employed Indian labour secured from the villages around them (Anderson, 1880). This was the first large commercial establishment for the production of dogfish oil in British Columbia. The livers of the dogfish (the only part of the shark processed in 1879) were first steamed in large vessels, in which the oil collected at the top. After separation, the oil was again subjected in another vessel to a certain degree of heat, thus dissipating very minute water particles. This refined oil was sealed in five-gallon cans, two of which were packed in a case for shipment to ready markets (Anderson, 1880). The quality of the dogfish oil could not be excelled for lubricating purposes at that time. In April, 1881, the best quality liver oil was used on the *H.M.S. Rocket* as a lubricating oil for the engines, and it was found that the dogfish oil was superior to the vegetable oils from Rangoon, used on Her Majesty's ships (Anderson, 1882).

During this period a very heavy duty which was placed on the highly prized dogfish oil almost prevented its export to the United States. Since the export market of oil was very limited, commercial fishing for the dogfish almost ceased and, as a result, a reduction occurred in the fishing effort. When the dogfish were no longer sought commercially they were regarded as a prevalent nuisance and a great annoyance to the fishermen in other branches of the fishing industry.

It was claimed that the dogfish would not only cut the fish lines but would also eat the fish on the hooks, leaving only the heads (Mowat, 1887). To help alleviate one of the complaints from many fishermen who deplored the dogfish as a pest because it destroyed valuable food fish, the Dominion Fisheries Commission of British Columbia (1908) recommended that the dogfish carcasses be marketed as a fresh fish. This product has appeared on the market at various times under such names as "whitefish", "ocean whitefish", and "flake".

It was not until the years 1916-18 that the dogfish on the Pacific coast were caught in large quantities for export to the fresh market. The name "greyfish" was given to the dogfish marketed as fresh fish and nearly the whole catch was exported to the United States of America. This market disappeared after the cessation of hostilities of World War I.

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FIG. 1.

Although great numbers of whole dogfish were utilized as cattle and chicken food (Cunningham, 1920), the dogfish continued to work havoc with the fishermen's nets. The British Columbia Fisheries Commission of 1922 (1923) strongly recommended, therefore, that the utilization of this pest by reduction plants be encouraged in some way, either by financial or other assistance, and that there be no restriction whatsoever placed on the catching of dogfish. The Commission also recommended, after further investigation, that a bounty should be paid for the catching of such fish if necessary.

At this time there was a restriction in the number of licenses issued to Orientals in the salmon and cod fisheries but since no restriction was placed on the number of hook and line dogfish licences given to Orientals, many Japanese turned to this industry.

With the increase in demand for Vitamin A the industry took note of Brocklesby's findings (1927) and a strong demand for dogfish liver developed. This was accelerated by increased needs for Vitamin A. The livers not only became increasingly important as a new source of Vitamin A but also established a record market value of 3·7 million dollars in 1944, which stood third place among British Columbia fisheries.

Prior to World War II the dogfish were caught by hook and line gear but in 1942 the cotton sunken gill-net was introduced into British Columbia and the power drum on the gill-net boats used for lifting such nets from the sea bottom was perfected. A typical sunken gill-net boat and the drum used to hold the net are shown in Figures 1 and 2. A diagram of a sunken gill-net set to catch dogfish is shown in Figure 3. From three to five nets are joined into one "string" or a "gang" of nets, and fished as one unit from 150 to 250 fathoms in length. In setting the net a marker pole and buoy are first put out, then the buoy line with the anchor attached follows. The boat moves ahead under power with the direction of the tide, while the net is payed out from the rotating drum. Another marker pole and buoy is attached to the other end of the net. A "string" of nets is usually left in the water 12 to 24 hours. Upon returning to the fishing grounds the fisherman lifts the marker pole and buoy into the boat and fastens the buoy line to a loop of rope on the axle of the drum. The buoy line and the net are now lifted from the sea bottom by the rotating drum which is driven by a shaft leading from the engine through a series of chain drives and a transmission system to the gear drive mounted on the axle of the drum (Figure 2). The dogfish are removed from the nets as they pass over the roller on the stern of the boat. After fishing operations the boats enter sheltered bays where the livers are removed from the dogfish into 40-pound capacity liver tins. The carcasses are then thrown overboard. In the Strait of Georgia the carcasses were placed on scows and delivered to a reduction plant where the oil was removed from the body of the dogfish and the remainder after processing was marketed as meal and fertilizer. Batch reduction of the carcasses is the only method technologically possible but exhaustive

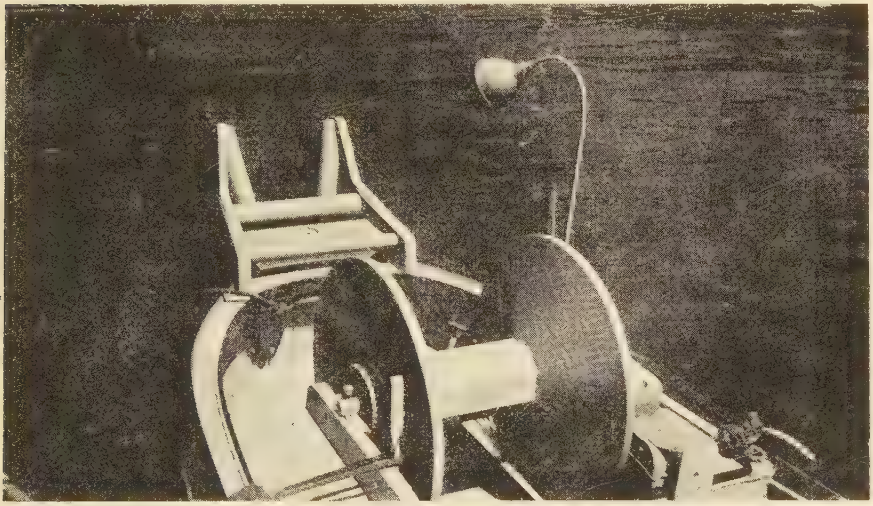

FIG. 2.

trials showed it to be economically impracticable under existing conditions and the reduction of the carcasses was abandoned in 1944 in the Strait of Georgia.

During the summer months the principal fishing grounds extend into Hecate Strait (Figure 4) and off the west coast of Vancouver Island. From 1943 and the years following, hundreds of boats, including sunken gill-net boats, longliners, and otter trawlers, gathered in Hecate Strait to exploit the vast populations which tended to migrate there. As a result of a high and increased fishing intensity the species was exploited to such a degree that a marked decline in the total landings of livers was recorded for the Province and a noticeable decline in the relative abundance or availability occurred in Hecate Strait (Figure 5).

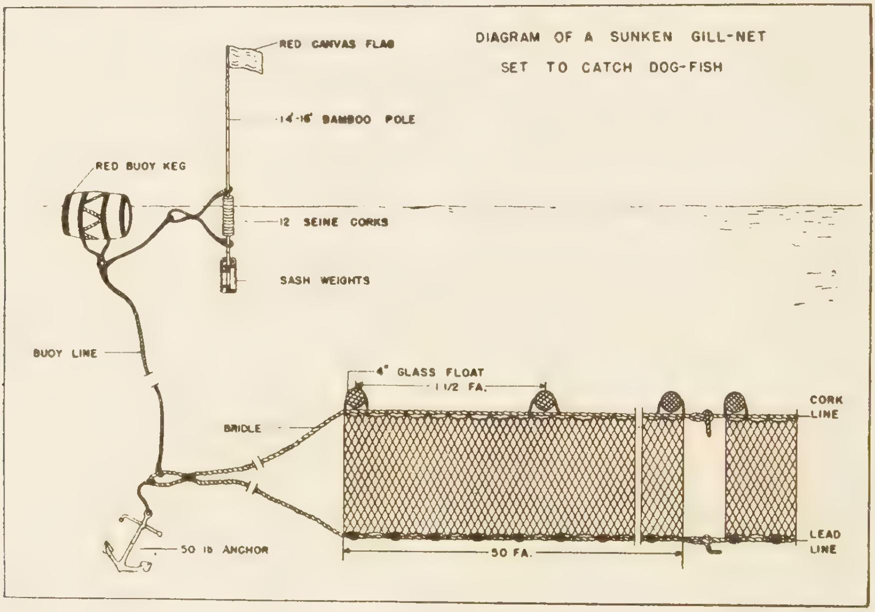
DIAGRAM OF A SUNKEN GILL-NET
SET TO CATCH DOG-FISH
RED CANVAS FLAG
14-16' BAMBOO POLE
RED BUOY KEG
12 SEINE CORKS
SASH WEIGHTS
BUOY LINE
4" GLASS FLOAT
1 1/2 FA.
BRIDLE
CORK LINE
LEAD LINE
50 lb ANCHOR
50 FA.

FIG. 3.

TABLE I
Quantity and Value of Dogfish Livers Landed in British Columbia from 1937 to 1946

	Weight Landed lb	*Value Dollars*	*Average Price Cents to Fishermen per lb.*
1937	178,900	10,702	6
1938	933,300	49,271	6
1939	308,047	19,063	6
1940	1,566,500	86,192	6
1941	3,552,576	331,737	9
1942	4,241,256	688,040	16
1943	5,121,186	1,344,858	25
1944	7,769,564	2,661,573	34
1945	5,821,849	1,833,210	31
1946	2,844,217	888,075	32

In addition to the decline in availability of dogfish and the total landings of livers from Hecate Strait there has been a noticeable decline in the Vitamin A potency of the dogfish livers from 1944 to

1947. The average Vitamin A potency (in U.S.P. units per gram of liver oil) of livers from dogfish caught in the same area in Hecate Strait (Figure 4) by sunken gill-nets has declined with each succeeding year since 1944. The decline is indicated in Table II. It is believed (Barraclough, 1948) that the decline in availability of the dogfish caught in sunken gill-nets in Hecate Strait is closely related to the removal of the older age classes of the dogfish from the population. The decline in the Vitamin A potency of the livers has been of great concern both to the fishermen and to the fishing industry.

TABLE II
The average number of U.S.P. units per gram of liver oil determined from the livers of dogfish which were landed only by sunken gill-nets in Hecate Strait, near the Queen Charlotte Island (Figure 4) from 1944 to 1947

	Average Number of U.S.P. Units per Gram of Liver Oil	*Total Poundage of Dogfish Livers Tested*
1944	14,648	148,191
1945	13,183	514,000
1946	9,784	446,448
1947	9,075	572,486

This species which at one time in the history of British Columbia contributed to the economy of the native Indians has thus passed through a period of condemnation and recrimination by commercial fishermen because it wrought destruction of their gear and of other

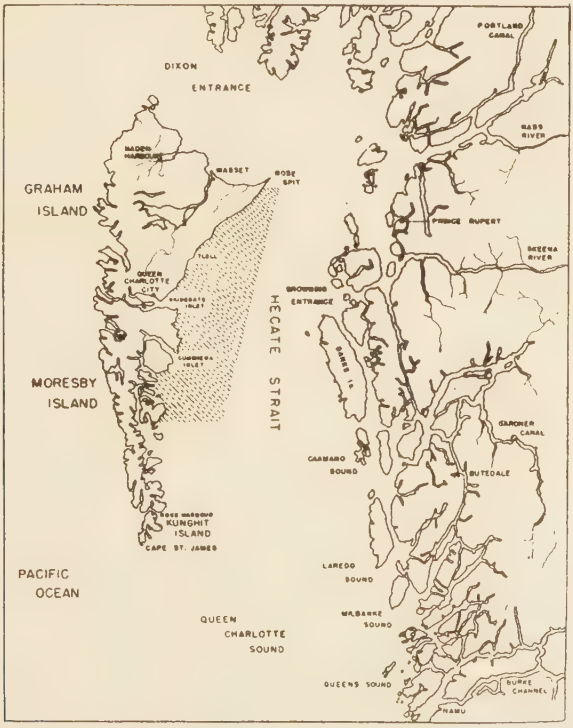
DIXON
ENTRANCE
PORTLAND CANAL
NASS RIVER
NADEN HARBOUR
MASSET
ROSE SPIT
GRAHAM ISLAND
PRINCE RUPERT
SKEENA RIVER
TLELL
QUEEN CHARLOTTE CITY
SKIDEGATE INLET
BROWNING ENTRANCE
HECATE STRAIT
BANKS IS.
CUMSHEWA INLET
MORESBY ISLAND
GARDNER CANAL
CAAMANO SOUND
BUTEDALE
ROSE HARBOUR
KUNGHIT ISLAND
CAPE ST. JAMES
PACIFIC OCEAN
LAREDO SOUND
MILBANKE SOUND
QUEEN CHARLOTTE SOUND
QUEENS SOUND
BURKE CHANNEL
NAMU

FIG. 4.–The shaded area indicates the general fishing grounds for the sunken gill-nets fishing for dogfish in Hecate Strait.

fish; growing needs for Vitamin A later led to the exaltation of this vermin to a place of prime importance in the seas off the British Columbia coast. It remains for technological research to discover economically advantageous methods of using the carcasses to produce body oil and fish meal or other products of value.

The removal of very large numbers of predators such as the dogfish must of necessity dislocate the economy of the coastwise waters. The exact change in the whole or main population resulting from vigorous pursuit of this fishery cannot be stated with certainty, but the first effects might be expected to include an increase in the forage species, such as herring, and increased opportunity for growth in competing predators such as salmon, ling, cod, and halibut. The inter-relationship of other species with the dogfish whose numbers can only be maintained at their expense requires further and continuous study. This is more imminent since the introduction of synthetic Vitamin A which renders the position liable to rapid economic change.

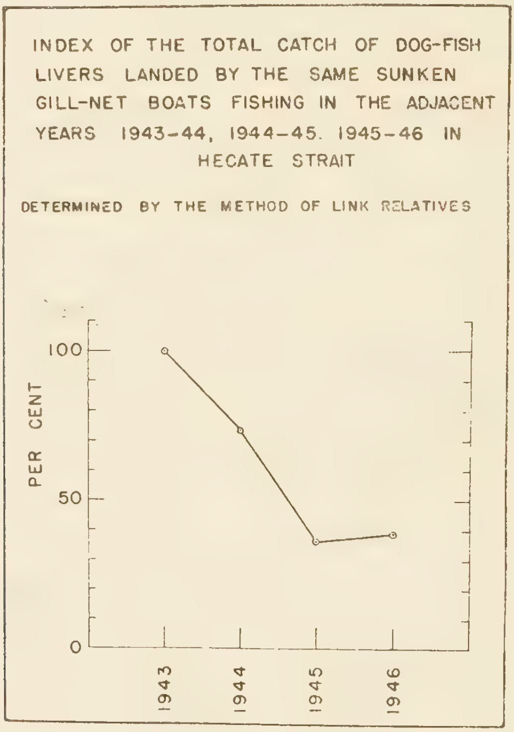

FIG. 5.

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A SURVEY OF MARINE WOOD BORERS IN THE PACIFIC BY THE UNITED STATES NAVY

Recorded by Charles H. Edmondson, Bishop Museum, Honolulu

The following report is a brief summary of the results of a survey of marine wood borers at fifteen stations, including eleven substations of the central, western and northern areas of the Pacific Ocean. The survey was initiated by the United States Navy, Bureau of Yards and Docks, Pearl Harbour, early in 1948, for a duration of six months, test blocks being installed during the first four months of that year. Included in the survey were the following stations:

Johnston Island
Tutuila, Samoa
Sangley Point, Cavite, Philippine Islands
Subic Bay, Philippine Islands (Four substations)
Okinawa
Tsingtao, China (Two substations)
Yokosuka, Japan
Koror
Truk Atoll
Kwajalein
Guam (Three substations)
Saipan (Two substations)
Adak, Alaska
Kodiak, Alaska
Midway Islands

The purpose of the project was to determine the incidence of marine borers at the different stations and thereby more accurately anticipate the durability or destruction of unprotected wood installations in the various areas covered by the survey. Also a study of the borers themselves, the taxonomic position of the species, their degree of activity and their dispersal are worthy matters of inquiry which naturally follow such an investigation.

Douglas fir wood was used as test blocks almost exclusively. White pine blocks were installed at Adak and Truk, and yellow pine at Tsingtao. At Sangley Point, in addition to Douglas fir, three Philippine woods, "Apitong (*Dipterocarpus* sp.), "Tanguile" (*Shorea* sp.) and "White cedar" (*Melia* sp.), were also utilized as test blocks. In size the test blocks were approximately 2 in. x 4 in. x 6 in., except at Kodiak where they were 2 in. x 4 in. x 12 in. Depth of submergence of test blocks generally ranged from 4 to 12 feet below the surface, except at Kodiak where they were secured 24 feet below the surface, and at Adak 58 feet below mean low water level. The blocks were examined after periods of submergence of three, four, five and six months.

Local conditions, without doubt, influence the activity of marine borers. Currents, depth of water, temperature, salinity and other factors are probably expressed in the destruction or durability of test blocks in any given locality. At Truk Atoll test blocks were free from infestation by marine borers during a period of four months (the longest interval available), although under very favourable temperature. (See Table I.) Their installation at Truk, 1,000 yards off the shore of Meon Island, may have subjected them to stronger currents or other conditions than would have been experienced in bays and harbours, and thereby rendered them less likely to be attacked by larval borers.

Because spawning of shipworms in northern latitudes is usually confined to the warmer portions of the year, test blocks in the colder zones frequently show little or no damage by teredos during the spring and early summer months. No attack by shipworms at Adak and Kodiak was seen throughout a period of six months, ending for Adak September 25, and for Kodiak August 1. The depth at which the blocks at Adak were placed (58 feet) together with the probable low temperature of the water throughout the period (42° F., surface temperature, June 25), may have contributed toward the results. At Kodiak, with blocks 24 feet below the surface, and surface temperature ranging from 41° F. on May 4 to 52° F. on August 1, no trace of action by teredos was seen. (See Table I.)

At Yokosuka, during intervals of three, four and five months, with surface temperature of water 63° F. April 20, 67·5° F. May 20, and 71° F. June 20, test blocks were free from attack by teredos. A block recovered July 20, surface temperature of water 73° F., however, showed slight infestation by shipworms. At Tsingtao (Pier 1) test blocks recovered May 15, June 12, and July 12, after intervals of three, four and five months, surface temperature of water 58° F., 72° F. and 75° F., respectively, were without attack by shipworms. After submergence for six months at this station, however, a test block showed moderate infestation by shipworms. On August 12, date of recovery of this test block, the reading for surface temperature of water was 77·4° F.

Although temperature may have influenced the activity of shipworms in the colder waters, the marine isopod *Limnoria* is apparently not affected to the same extent by this factor. *Limnoria* was constantly present at the northern stations. At Kodiak, at a depth of 24 feet, the isopod was quite active during the first three months of the survey and increasingly so at later intervals. A trace of *Limnoria* was seen in test blocks at Adak (depth 58 feet) on each of the four examinations. At the other two stations above 30° N. Lat., Tsingtao and Yokosuka, *Limnoria* attacked test blocks during the first 90 days and showed increasing activity in the following months. Damage by the isopod at the Tsingtao station (Pier 1) was slightly greater than at Yokosuka.

Considerable amounts of external fouling attached to test blocks seem to have some influence in retarding marine borer activities. During the survey test blocks from Midway Islands were consistently densely fouled, carrying much heavier loads than blocks from other stations. These heavily fouled blocks were at no time more than lightly attacked by shipworms and moderately infested by *Limnoria*. In 1939 piling from the lagoon at Midway, provided by the U.S. Army Engineers, was examined. This piling, free from external fouling, gave evidence of much greater activity by marine borers at this station than is indicated by the test blocks of the recent survey.

The survey clearly shows marine borers to be a serious potential menace to unprotected wood installations throughout the warmer waters of the central and western Pacific. At certain stations, as Saipan, Guam and those of the Philippine Islands, from eight to ten species of borers were recovered from individual test blocks. In other localities fewer species were present. In Pago Pago Harbour, Samoa, the destructions of test blocks was caused primarily by one species with a few others assisting sparingly. At Tsingtao but a single species of *Teredo* was responsible for moderate damage to test blocks during an interval of six months.

Taxonomic and distributional studies of the marine borers recovered during the survey are now in progress. Preliminary observations indicate a wide dispersal of certain species of shipworms. Several species typical of Hawaiian waters occur at Saipan, Guam and other western Pacific stations. The peak of ocean traffic by surface craft during the war years may have had much to do in effecting this apparent distribution of marine borers toward the west. There is also some evidence of a reversed dispersal, from west to east. A very distinctive species of *Teredo* common at Guam, and occurring at Okinawa, Kwajalein and in Subic Bay, was recovered from a test block in Honolulu Harbour during September, 1948, for the first time.

A synopsis of stations and substations covered by the survey follows, with specific locations of test blocks, and briefs of marine borer activities as observed after periods of three, four, five and six months. The term Teredinidae, as used below, includes shipworms of the genera *Teredo, Bankia,* etc. The bivalve mollusk, *Martesia,* which occurs at Guam and is abundant at the Philippine stations, is a wood borer of the family Pholadidae. *Limnoria,* a well-known marine isopod, is cosmopolitan in distribution but becomes a greater menace in certain localities than others. Rapid destruction of test blocks by this organism occurred at Samoa, Okinawa and Saipan. The amphipod, *Chilura,* sometimes associated with *Limnoria* in wood destruction, especially in tropical and subtropical waters, was observed during the survey in test blocks from Samoa only.

In carrying out the survey the co-operation by personnel of the several stations was very gratifying. From most stations a full quota of test blocks was received covering the entire duration of the survey (six months), as originally contemplated. At the time of this report the following shortages are reported:

Johnston Island—Test blocks for 5th and 6th months.
Tsingtao (Buoy # 6)—Test blocks for 5th and 6th months.
Koror—Test block for 6th month.
Truk Atoll—Test blocks for 5th and 6th months.

Table I of the report sets forth the dates of recovery of the test blocks at the different stations, and also the readings of surface temperature of the seawater taken at the same time. The photographs which accompany the report present a comparative view of the activities of marine borers at 15 stations. The test blocks are sawed lengthwise through the middle, those selected showing results after submergence for five months, except where otherwise indicated.

TABLE I.—DATES OF REMOVAL OF TEST BLOCKS, AND SURFACE TEMPERATURE OF WATER AT THE TIME, AFTER SUBMERGENCE FOR 3, 4, 5 AND 6 MONTHS (- - - - - INCOMPLETE RECORD)

	3 Months	*4 Months*	*5 Months*	*6 Months*
Johnston Island	April 27 77·4 F.	June 1 78·5° F.	- - - - -	- - - - -
Tutuila, Samoa	April 30 85° F.	May 30 84° F.	June 30 - - - - -	July 30 80° F.
Sangley Point	April 27 - - - - -	May 21 - - - - -	June 21 85·1° F.	July 21 81·5° F.
Subic Bay				
Coaling Dock	May 1 80° F.	June 1 70° F.	July 1 72° F.	August 1 75° F.
Boat Pool	May 1 75° F.	June 1 70° F.	July 1 72° F.	August 1 75° F.
Alava Dock	May 1 75° F.	June 1 70° F.	July 1 72° F.	August 1 75° F.
N.S.D. Dock	May 1 75° F.	June 1 70° F.	July 1 72° F.	August 1 75° F.
Okinawa	April 28 67° F.	May 28 64° F.	June 29 68° F.	August 2 69° F.
Tsingtao, China				
Pier 1	May 15 58° F.	June 12 72° F.	July 12 75·9° F.	August 12 77·4° F.
Buoy # 6	June 3 70° F.	July 3 80° F.	- - - - -	- - - - -
Yokosuka, Japan	April 20 63° F.	May 20 67·5° F.	June 20 71° F.	July 20 73° F.
Koror	May 1 - - - - -	June 1 - - - - -	July 14 81° F.	- - - - -
Truk Atoll	May 5 78° F.	June 3 83° F.	- - - - -	- - - - -
Kwajalein	July 22 - - - - -	August 22 81° F.	Sept. 22 81° F.	Oct. 22 81° F.
Guam—Three substations	April 27 86° F.	May 28 86° F.	July 1 86° F.	August 1 - - - - -
Saipan—Two substations	April 30 84·5° F.	May 30 86° F.	June 30 85·5° F.	July 30 85·5° F.
Adak, Alaska	June 25 42° F.	July 25 - - - - -	August 25 - - - - -	August - - - - -
Kodiak, Alaska	May 4 41° F.	June 3 41° F.	July 1 44° F.	August 1 52° F.
Midway Islands	April 22 70·7° F.	May 24 71° F.	June 24 75° F.	July 22 72° F.

STATIONS

Johnston Island

Beneath boat docks of N.A.F.

Three months—Moderate damage by Teredinidae. No trace of action by *Limnoria*.

Four months—Moderate damage by Teredinidae. A trace of action by *Limnoria*. Fig. 1.

Five months—Wanting.

Six months—Wanting.

Tutuila, American Samoa

On a reef in Pago Pago Harbour.

Three months—Riddled by Teredinidae. Light attack by *Limnoria* and *Chelura*.

Four months—Riddled by Teredinidae. Moderate action by *Limnoria* and *Chelura*.

Five months—Riddled by Terdinidae. Heavy damage by *Limnoria* and *Chelura*. Fig. 2.

Six months—Riddled by Teredinidae and *Limnoria*.

Sangley Point, Cavite, Philippine Islands

Off Naval Air Station.

Three months—

- Douglas fir—Heavy attack by Teredinidae and *Martesia*. No action by *Limnoria*.
- Apitong—Light attack by Teredinidae and *Martesia*. No action by *Limnoria*.
- Tanguile—Light attack by Teredinidae. Moderate damage by *Martesia*. No action by *Limnoria*.
- White cedar—Light attack by Teredinidae. Moderate damage by *Martesia*. No action by *Limnoria*.

Four months—

- Douglas fir—Riddled by Teredinidae and *Martesia*. No trace of *Limnoria*.
- Apitong—Light attack by Teredinidae and *Martesia*. No action by *Limnoria*.
- Tanguile—Light action by Teredinidae. Heavy attack by *Martesia*. No trace of *Limnoria*.
- White cedar—Very lightly attacked by Teredinidae. Moderate damage by *Martesia*. No trace of *Limnoria*.

Five months—

- Douglas fir—Riddled by Teredinidae and *Martesia*. Action by *Limnoria* negligible. Fig. 3.
- Apitong—Moderate attack by Teredinidae and *Martesia*. Action by *Limnoria* negligible.
- Tanguile—Riddled by *Martesia*. Action by Teredinidae and *Limnoria* negligible. Fig. 4.
- White cedar—Riddled by *Martesia*. Action by Teredinidae and *Limnoria* negligible.

Six months—

- Douglas fir—Riddled by Teredinidae. Slight action by *Martesia* and *Limnoria*.
- Apitong—Moderate damage by Teredinidae. Light action by *Martesia*. *Limnoria* negligible.
- Tanguile—Riddled by *Martesia*. Light attack by Teredinidae. *Limnoria* negligible.
- White cedar—Badly damaged by *Martesia*. Light attack by Teredinidae. *Limnoria* negligible.

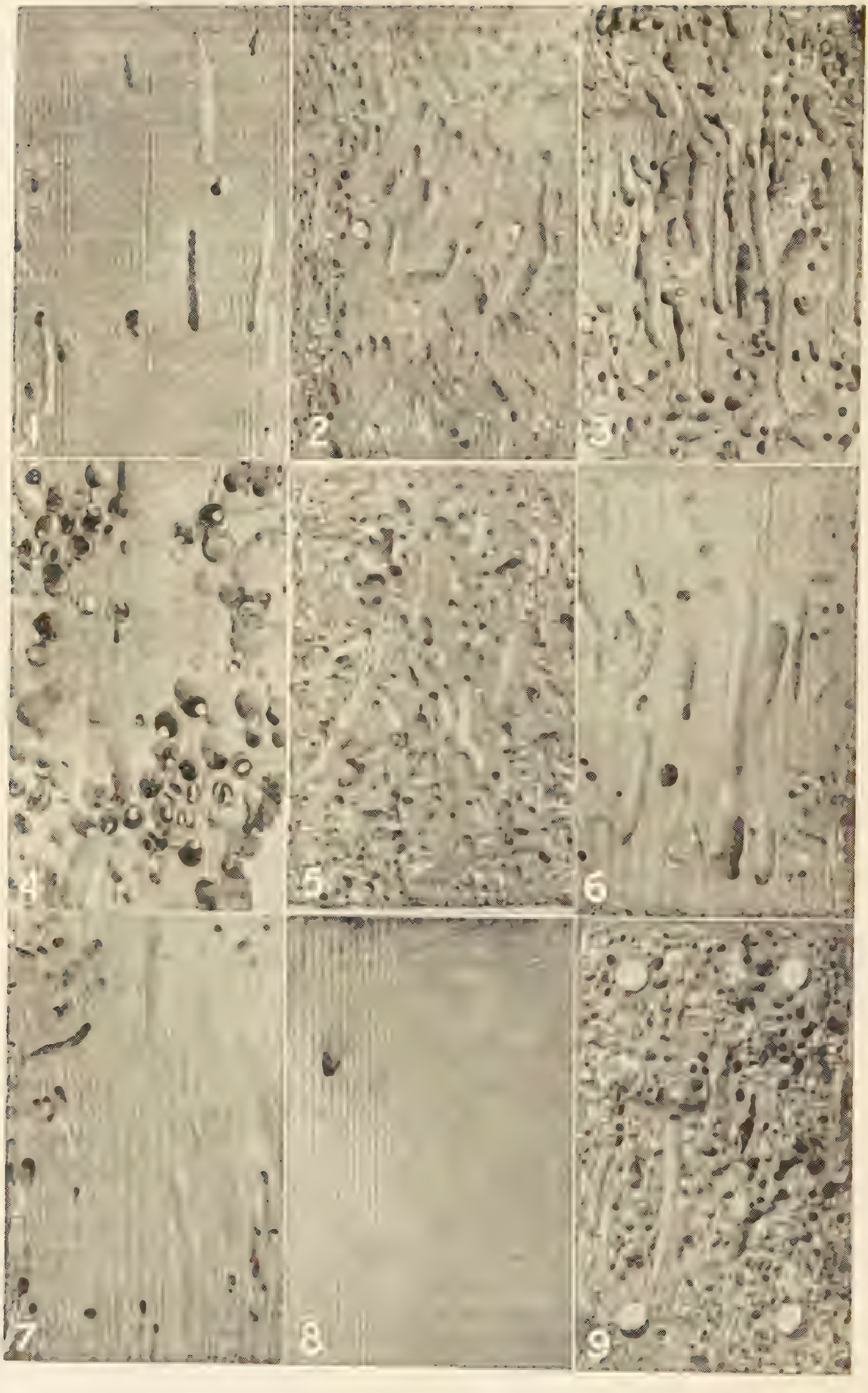
Subic Bay, Philippine Islands (Pine test blocks)

Pre-war Coaling Dock, east coast of Subic Bay.

Three months—Heavy damage by Teredinidae. Light action by *Martesia*. Slight action by *Limnoria*.

Four months—Heavily attacked by Teredinidae. Action by *Martesia* light, by *Limnoria* negligible.

Five months—Badly damaged by Teredinidae and *Martesia*. No trace of action by *Limnoria*.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Six months—Riddled by Teredinidae (*Teredo* and *Bankia*). Heavy attack by *Limnoria;* light action by *Martesia.*

Small Boat Pool Area, southern coast of Inner Basin.

Three months—Heavy damage by Teredinidae. Light attack by *Martesia.* No trace of action by *Limnoria.*

Four months—Heavy attack by Teredinidae. Light action by *Martesia. Limnoria* negligible.

Five months—Badly damaged by Teredinidae and *Martesia.* No action by *Limnoria.*

Six months—Riddled by Teredinidae; slight action by *Limnoria.*

Alava Dock Area, north-east coast of Subic Bay, fronting the Naval Base.

Three months—Heavy damage by Teredinidae. No trace of *Martesia* or *Limnoria.*

Four months—Heavy damage by Teredinidae. No action by *Martesia* or *Limnoria.*

Five months—Badly damaged by Teredinidae. Heavy attack by *Limnoria.* No action by *Martesia.* Fig. 5.

Six months—Riddled by Teredinidae; slight action by *Limnoria.*

N.S.D. Dock Area, northern coast of Subic Bay, about five miles north-west of Naval Base.

Three months—Heavy damage by Teredinidae. No action by *Martesia* or *Limnoria.*

Four months—Heavy damage by Teredinidae. No action by *Martesia* or *Limnoria.*

Five months—Badly damaged by Teredinidae. No trace of *Martesia* or *Limnoria.*

Six months—Riddled by Teredinidae; slight action by *Limnoria* and *Martesia.*

Okinawa

Test blocks installed along side of Naha Harbour Dock.

Three months—Moderate attack by Teredinidae. Heavy infestation by *Limnoria.*

Four months—Badly damaged by Teredinidae and *Limnoria.*

Five months—Badly damaged by Teredinidae and *Limnoria.* Fig. 6.

Six months—Badly damaged by Teredinidae; some specimens penetrating to depths exceeding 100 mm. Heavy attack by *Limnoria.*

Tsingtao, China

Pier No. 1, west end, Second Mooring Bit.

Three months—(P-1) No trace of Teredinidae. Slight attack by *Limnoria.*

Four months—(P-2) No trace of Teredinidae. Light attack by *Limnoria.*

Five months—(P-3) No trace of Teredinidae. Moderate attack by *Limnoria.*

Six months—(P-4) Moderate attack by Teredinidae. Moderate action but slight penetration by *Limnoria.* Fig. 7.

Buoy # 6, Outer Harbour.

Three months—(O.H.-1) No trace of action by Teredinidae or *Limnoria.* Surface of test block heavily coated by masses of marine amphipod, *Jassa* sp.

Four months—(O.H.-2) No trace of action by Teredinidae or *Limnoria.* Masses of *Jassa* adhering to test block.

Five months—Wanting.

Six months—Wanting.

Yokosuka, Japan

Harbour Pier (floating dock).

Three months—No trace of Teredinidae. Very light action by *Limnoria.*

Four months—No trace of Teredinidae. Very light action by *Limnoria.*

Five months—No trace of Teredinidae. Light attack by *Limnoria.*

Six months—Very light attack by Teredinidae; one specimen penetrating 70 mm, few others 10-15 mm. Light action by *Limnoria.* Fig. 8.

Koror

About 200 yards north-west of Ebeduls Dock.

Three months—Moderate attack by Teredinidae. No trace of action by *Limnoria.*

Four months—Riddled by Teredinidae. Light attack by *Limnoria.*
Five months—Riddled by Teredinidae. Light attack by *Limnoria.* Fig. 9.
Six months—Wanting.

Truk Atoll
Test blocks secured to buoy of Station Craft YOG 79, 1,000 yards off west shore of Moen Island.
Three months—No trace of Teredinidae or *Limnoria.*
Four months—No trace of Teredinidae or *Limnoria.* Fig. 10.
Five months—Wanting.
Six months—Wanting.

Kwajalein
Suspended beneath the YR-68 moored alongside the AFDL-19.
Three months—Moderate attack by Teredinidae, some specimens exceeding 100 mm. in length; no action by *Limnoria.*
Four months—Badly damaged by Teredinidae; very slight action by *Limnoria.*
Five months—Badly damaged by Teredinidae; slight action by *Limnoria.* Fig. 11.
Six months—Riddled by Teredinidae; slight action by *Limnoria.*

Guam
Block # 1—Outer end of Pier Uncle.
Three months—Riddled by Teredinidae. No trace of action by *Limnoria.*
Four months—Riddled by Teredinidae. Light attack by *Limnoria.*
Five months—Riddled by Teredinidae and *Martesia.* Light attack by *Limnoria.*
Six months—Riddled by Teredinidae. Light attack by *Martesia* and *Limnoria.*
Block # 2—Inshore end of Pier Victor.
Three months—Heavily attacked by Teredinidae. Moderate action by *Limnoria.*
Four months—Badly damaged by Teredinidae. Moderate action by *Limnoria.*
Five months—Riddled by Teredinidae and *Martesia.* Light action by *Limnoria.* Fig. 12.
Six months—Riddled by Teredinidae. Light action by *Martesia.* Moderate attack by *Limnoria.*
Block # 3—Outshore end of George Dock.
Three months—Heavily attacked by Teredinidae. No trace of action by *Limnoria* or *Martesia.*
Four months—Riddled by Teredinidae. Moderate action by *Limnoria.* No trace of action by *Martesia.*
Five months—Riddled by Teredinidae and *Martesia.* Light action by *Limnoria.*
Six months—Riddled by Teredinidae. Light attack by *Limnoria.* No trace of action by *Martesia.*

Saipan
Block A—End of Pier Able.
Three months—Badly damaged by Teredinidae, maximum penetration 90 mm. Heavy attack by *Limnoria.*
Four months—Heavy attack by both Teredinidae and *Limnoria.*
Five months—Riddled by Teredinidae and *Limnoria.* Fig. 13.
Six months—Riddled by Teredinidae and *Limnoria.*
Block B—End of Boat Repair Basin.
Three months—Heavy attack by Teredinidae. Slight action by *Limnoria.*
Four months—Riddled by Teredinidae. Lightly attacked by *Limnoria.*
Five months—Riddled by Teredinidae. Moderate action by *Limnoria.*
Six months—Riddled by Teredinidae. Moderate action by *Limnoria.*

Adak, Alaska
Pier 10, Sweeper Cove. Depth of submergence 58 feet.
Three months—No trace of Teredinidae. A trace of action by *Limnoria.*
Four months—No trace of Teredinidae. A trace of action by *Limnoria.*
Five months—No action by Teredinidae. Slight action by *Limnoria.* Fig. 14.
Six months—No trace of Teredinidae. Slight action by *Limnoria.*

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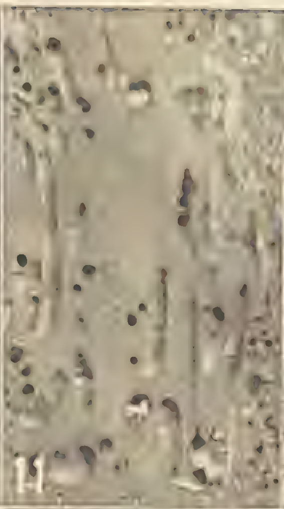
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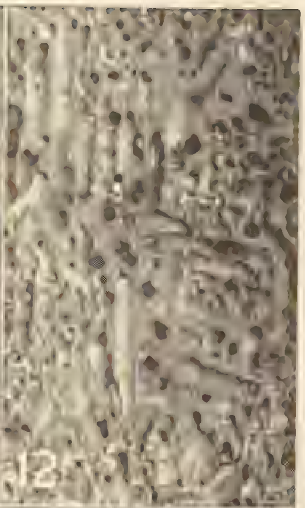
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Kodiak, Alaska

Temporary Pier, Womans Bay. Depth of submergence 24 feet.

Three months—No trace of action by Teredinidae. Rather heavy attack by *Limnoria*.

Four months—No action by Teredinidae. Heavy attack by *Limnoria*.

Five months—No action by Teredinidae. Heavy attack by *Limnoria*. Fig. 15.

Six months—No action by Teredinidae. Heavy attack by *Limnoria*. Fig. 16 (surface, enlarged).

Midway Islands

Off Pier.

Three months—Very light attack by Teredinidae. Action by *Limnoria* moderate.

Four months—Very light attack by Teredinidae. Action by *Limnoria* light.

Five months—Light attack by Teredinidae; most specimens of small size, one 70 mm. in length. Moderate action by *Limnoria*. Fig. 17.

Six months—Slight damage by Teredinidae, maximum penetration 40 mm. Moderate action by *Limnoria*.

SUMMARY

A very high incidence of marine wood borers is indicated at most stations in the warmer waters of the Pacific covered by the survey.

Test blocks of such susceptible woods as Douglas fir were riddled by shipworms within 90 days in Pago Pago Harbour, at Sangley Point, in Subic Bay, at Guam and Saipan. More sluggish activity of marine borers at some stations may possibly be accounted for by local conditions as temperature, currents, external fouling, position of installation of test blocks, etc.

Lack of infestation of test blocks at Truk Atoll during four months is probably due to selection of position for their installation (1,000 yards off Moen Island), as apparently they were under favourable thermal conditions. This suggestion, however, cannot be further supported because of incomplete records from this station.

Heavy external fouling of test blocks at Midway Islands probably retarded the action of marine borers. This factor may also be cited in case of substation Buoy # 6, at Tsingtao, where test blocks were consistently heavily coated by adhering masses of the marine amphipod, *Jassa* sp., but showed no borer activity during four months.

The low temperature of the water at Adak and Kodiak, Alaska, is probably correlated with the absence of shipworm activity at those stations throughout the entire survey. In northern waters spawning of Teredinidae occurs during the warmest season of the year, therefore, lack of infestation of test blocks at Adak and Kodiak by shipworms is not surprising.

Destruction of wood by the marine isopod, *Limnoria*, does not always parallel that caused by the Teredinidae. During the survey the most rapid and serious damage to test blocks by *Limnoria* was seen at Samoa, Okinawa and Saipan. Action by the isopod was almost negligible at Sangley Point, and slow and erratic in Subic Bay, where not until the fifth and sixth months was moderate to heavy infestation seen. At other stations action ranged from a trace to moderate attacks. *Limnoria* was detected in all test blocks from Adak (depth 58 feet), and heavy infestation at Kodiak (depth 24 feet) occurred, although the blocks were not seriously damaged.

At Sangley Point, the Philippine woods "Apitong", "Tanguile" and "White cedar", are very susceptible to the pholad mollusk, *Martesia,* which caused rapid destruction of "Tanguile" and "White cedar". Of the three woods, "Apitong" seems to be the most durable in sea water. *Martesia* is also a menace to untreated wood in Subic Bay, and also appeared in test blocks at Guam.

TIMBERS OF UNUSUAL RESISTANCE TO MARINE BORERS IN HAWAIIAN WATERS

By Charles H. Edmondson, Bishop Museum, Honolulu

Nearly 400 timbers from many parts of the world, during the past twelve years, have been given sufficient tests in Hawaiian waters to place them in categories of "non-resistant" or "unusually resistant" to the ravages of marine borers.

It is safe to say that no natural timber has yet been discovered that is immune to marine borers. A few, however, mostly from tropical and subtropical forests, are endowed with properties of more than usual durability in sea water. Substances such as silica, alkaloids, oils, resins and tannins, held in considerable amounts in certain woods, are reputedly more or less adverse to the action of marine borers and, doubtless, other more obscure elements should be added to this list of retarding agents.

Needless to say, the "unusually resistant" category of timbers tested in Hawaiian waters is small, and may be further reduced by current and future investigations. The woods which seem worthy of consideration are those that by repeated tests have well resisted continuous action of marine borers for periods ranging from one to approximately four years.

Some of these are well-known timbers with reputations for durability in sea water already established. Others are newcomers to this field, whose lasting qualities, when challenged by marine borers, are indicated but are yet to be fully demonstrated.

It is obvious that one year is inadequate in which to properly evaluate the life of certain timbers, but in waters known to be constantly saturated with larvae of marine borers, a year's submergence does give some indication of durability or lack of it. Timbers that stand up well in Honolulu Harbour, which probably is as severe a "proving ground" as can be found anywhere, for one, two, three or more years, are at least worthy of honourable mention.

Destructive agents among the Teredinidae in Hawaiian waters include about a dozen species of *Teredo* and three or four of *Bankia.* The pholad mollusk, *Martesia,* has invaded many bays and harbours, but is not yet a serious menace at the testing station in Honolulu Harbour. Of crustacean borers, *Limnoria* is the most devastating. Few natural timbers are free from its ravages, which extend to woods adequately creosoted to restrain the action of teredos. *Chelura* is sometimes associated with *Limnoria* but, in this locality, has been observed only in such woods as firs and pines.

Timbers here considered are listed under regional areas representing the origin of wood samples tested.

Family Cupressaceae

Callitris glauca R. Br. (= *C. robusta* R. Br.). Cypress pine. This wood (Australian grown) has proved to be one of the most durable yet tested in Hawaiian waters. During an interval of nearly four years few teredos have entered the wood, with a maximum penetration of 15 mm. The wood is also unusually resistant to *Limnoria,* with hardly a trace of action by the isopod.

The qualities of this timber, repellant to marine borers and also to termites, are probably due to "Callitris acid" and resinous material, as determined by I. W. Dadswell and H. E. Dadswell, and reported in *Journ. Council for Scientific and Industrial Research,* Vol. 4, pp. 208-216, 1931.

A few hundred trees of *Callitris* have been planted in Hawaii during recent years, being tried out by the Board of Agriculture and Forestry as a watershed cover. Apparently no commercial use of the timber has yet been made in Hawaii in construction work, either land or marine.

Family Myrtaceae

Syncarpia laurifolia Ten. Turpentine tree. Australian-grown sections of the turpentine tree have stood up well in Honolulu Harbour against constant attack by marine borers for nearly four years. Up to the present time its resistance to shipworms is comparable to that of *Callitris glauca.* Very few teredos have become established in the wood, with slow progress. At this station, however, *Limnoria* seems to be a serious menace to the turpentine tree, greater damage having been done to Australian-grown sections by the isopod than by teredos.

A rather surprising observation has been made regarding *Syncarpia laurifolia.* The tree has been planted extensively in Hawaii during the past thirty-five or forty years, being useful as a watershed cover. Earlier plantings now include trees up to about two feet in diameter. Heartwood from some of the larger trees grown on Kauai shows a marked susceptibility to marine borers. An amazing contrast in durability is seen when the Hawaiian wood is tested alongside Australian-grown sections.

Dr. H. E. Dadswell, of the Forest Products Laboratory, South Melbourne, Australia, who has expressed interest in the apparent difference in resistant qualities of Australian- and Hawaiian-grown *Syncarpia laurifolia,* found the silica content of Hawaiian samples of *Syncarpia,* which I forwarded to him, as low as 0·08 per cent, as compared with an average of 0·58 per cent for various samples of the Australian-grown species. My chemist has recorded silica as high as 0·13 per cent in some Hawaiian-grown samples. Gonggrijp suggested that silica content lower than 0·50 per cent would probably not have much influence on marine borer activities.

It is quite likely that by reason of rapid growth in Hawaii, the turpentine tree has not acquired repellent properties which may accumulate with age and greater maturity. Whatever may be the answer, it is obvious that untreated timbers of *Syncarpia laurifolia,* grown in Hawaii at the present time, could not be economically utilized in marine structures.

SOUTH AMERICAN AND CARIBBEAN TIMBERS

For annotations on woods of South America and the Caribbean area I am chiefly indebted to "Timbers of Tropical America" by Record and Mell, Yale University Press, 1924.

Family Euphorbiaceae

Hieronyma laxiflora Muell.-Arg. Suradan of Br. Guiana. Probably not distinct from *H. alchorneoides* Allem. A hard, heavy timber, difficult to cut and split; apparently quite durable. Used widely in general construction work, including boat building.

Honolulu Harbour, 13 months, very lightly attacked by teredos, maximum penetration 10 mm. No trace of *Limnoria.*

Family Lauraceae

Nectandra sp. Wane of Dutch Guiana. The wood of this timber seems to be tough, hard and durable. Heartwood pale brown in colour.

Honolulu Harbour, 14 months, no attack by teredos and no trace of *Limnoria.*

Ocotea rodiaei (Schom.) Mez. Greenheart of Br. Guiana. A well-known timber having a reputation for great durability in sea water. Heartwood ranging in colour from light to dark olive or nearly black. Sapwood pale yellow, becoming greenish on exposure. Material, pronounced to be heartwood, was received from several sources and tested in Honolulu Harbour.

Samples of light olive heartwood showed slight to moderate attacks by teredos during intervals up to two years. Maximum penetration 35 mm. Attacks by *Limnoria* were more serious, considerable damage to test blocks being done within one year.

Attacks by teredos on dark olive heartwood were negligible during intervals up to four years, but after about three years very pronounced damage by *Limnoria* was noted.

Chemical analysis of the light coloured heartwood indicated silica 0·02 per cent; tannins, very light; alkaloids, heavy. Alkaloids have long been recognized as elements responsible for the durability of greenheart. With this timber, however, as with others, marked variation occurs in wood from different sources, and doubtless from different parts of the same tree. The darker coloured greenheart, which was observed by Yale School of Forestry to possess a higher content of oily substance than lighter coloured samples, has consistently presented superior resistance to teredos.

Continued examination of this timber is being made in Hawaiian waters. It seems obvious that certain grades of the wood do greatly retard the activities of teredos, but the same degree of repugnance apparently does not extend to crustacean borers in this locality.

Ocotea rubra Mez. Determa of Br. Guiana. A large, tall tree with light reddish brown wood, coarse grained, hard and strong. It is said to be resistant to termites. The timber is used for furniture, boat planking and dugout canoes.

Honolulu Harbour, 15 months, heartwood but slightly attacked by teredos, or not at all. No trace of *Limnoria.*

Family Lecythidaceae

Cariniana pyriformis Miers. Bacú of Venezuela; Albarco of Colombia. A very large tree; heartwood brownish in colour, not sharply demarcated from sapwood, firm and tough. A high silica content is suggested but, so far as I am aware, has not been confirmed.

Honolulu Harbour, 14 months, very light attack by teredos with maximum penetration of 10 mm. No action by *Limnoria*.

Eschweilera sagitiona Miers. Black kakeralli of Br. Guiana. A medium to large tree very close to *E. longipes* (Poit), known as manbarklak. Heartwood olive brown to reddish brown; sapwood yellow. A hard, heavy, tough and highly durable wood. A high silica content, as in *E. longipes,* is suggested.

Honolulu Harbour, two years, very light attack by teredos and *Limnoria,* maximum penetration of the former 10 mm.

Lecythis paraensis (Huber) Ducke. Castanha sapucaia of Puerto Rico. According to Record and Mell, woods of this genus are mostly hard, heavy, tough and strong; some are durable, others are not. Heartwood brown or yellowish brown. Wood used in heavy construction as bridges, railway ties, posts, and also utilized in carpentry and cabinetwork.

Honolulu Harbour, 14 months, very lightly attacked by teredos, or not at all. No trace of action by *Limnoria.*

Family Moraceae

Brosimum paraense Huber. Cardinal wood of South America. Also known as murapiranga (red wood). A rather tall tree but not large in girth. Heartwood reddish, straight grained, hard, heavy and highly durable. The presence of gum is observed among the wood fibres.

Honolulu Harbour, 14 months, very light attack by teredos, or none at all. No trace of action by *Limnoria.* An undetermined species of *Brosimum,* with a trade name of "Guatemala wood" is riddled by teredos in six months.

Family Rosaceae

Licania densiflora Kleinh. Marishiballi of Br. Guiana.

Trees of this genus are small to large; heartwood light brownish, heavy, hard and tough. Said to be used for heavy construction not in contact with the ground. Inclined to decay rather quickly.

Honolulu Harbour, 14 months, very light attack by teredos, or none at all. No action by *Limnoria.*

HAWAIIAN TIMBERS

Family Euphorbiaceae

Antidesma platyphyllum Mann. Hame or Haa.

Antidesma pulvinatum Hillebrand. Haa or Mehame. Both of these species, endemic in Hawaii, give promise of considerable resistance to marine borers. The durability of these woods, during intervals exceeding three years, compare favourably with the greenheart of South America, and the turpentine tree and cypress pine of Australia. Larvae of teredos readily attack the surface of the wood, sinking to depth of the diameter of the larval shell, but few borers are successful in becoming established. Up to now, the maximum penetration by teredos is approximately 15 mm. Damage to test blocks by *Limnoria* is slight or negligible. A significant observation is that the sapwood is apparently no more susceptible to marine borers than is the heartwood.

The chemical analysis probably offers an explanation for the unusual durability of these woods in sea water. Results are as follows: for *A. pulvinatum*, silica, average of several samples, 1·86 per cent; tannins, medium; alkaloids, none.

No commercial value is attached to these timbers in Hawaii. They are small trees, slightly exceeding 1 foot in diameter and 20-30 feet tall. For the most part they grow in remote and often inaccessible parts of the islands. The timber might be useful in light marine construction, or its lumber as planking for small boats.

Family Verbenaceae

Vitex parviflora Juss. Molave. A native tree of the Philippine Islands, reaching a height of about 50 feet; planted in Hawaii as a watershed cover but not yet attaining full growth. Wood pale brown in colour, very hard; little distinction between sapwood and heartwood in juvenile material examined.

Honolulu Harbour, intervals ranging up to 22 months, very lightly attacked by teredos and *Limnoria*. Test blocks essentially as sound at the end of the test period as when installed. Chief vulnerable spots open to attack by marine borers are fault areas, as knots. Chemical analysis: silica, less than 0·01 per cent; tannins, heavy; alkaloids, none.

Vitex pubescens Vahl. Malayan teak. A large tree attaining a height of 80 feet, native of south-eastern Asia and Malaysia, has been planted in Hawaii as a watershed cover but has not yet reached maturity here. Wood of juvenile sections examined, pale yellow, almost white; little distinction between sapwood and heartwood.

Honolulu Harbour, 30 months, but lightly attacked by teredos, maximum penetration 28 mm. Slight action by *Limnoria*. Chemical analysis not determined.

By the reaction of juvenile wood of these two species of *Vitex* to marine borers, it can be predicted with some degree of certainty that mature timber would present even greater resistance. The capacity to check the action of marine borers, however, is a specific characteristic among timbers, not a generic or family one. Two other species of *Vitex* examined, *V. divaricata* Sw. and *V. vestitia* Wall., are almost totally destroyed within 12 months.

CORAL-DWELLING ORGANISMS AS DESTRUCTIVE AGENTS OF CORALS

By Huzio Utinomi, Seto Marine Biological Laboratory,
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In tropical seas many animals and plants live in association with corals and form a composite biotic entity; they also play an important role in the economy of coral reefs as a whole. Considering the undoubted importance of these organisms, especially in the destruction of reef corals, it is surprising what diverse views have been expressed by workers engaged in this subject. It is generally admitted, however, that the action of boring organisms is the most important of all biological agencies of destruction.

Gardiner,[1] who examined many reefs, lays special stress on the importance of these organisms as destructive agencies. He considers the softening of the reef by boring Algae to be the principal cause of destruction, being probably more important than the action of all other boring organisms taken together. This view is followed by Bertram[2] who worked at Ghardaqa Reef, Red Sea. Finckh[3] and Otter[4] also have demonstrated the importance of boring organisms in coral reef destruction. On the other hand, Wood-Jones[5] who has worked on the problem at Cocos Keeling Atoll, tends to consider the effect of boring organisms as indirect or even slight, as they are only a minor cause of the death of living corals. He says: "There seems to be indeed an almost symbiotic relation between certain boring animals and the corals that they have chosen as their hosts, for coral growth extends and strengthens their tubes by sympathetic growth, and the cavities of the molluscs in many cases expand the living area of the surface of corals by causing irritation and repair."

In this connection, it should be taken into account that the death of coral polyps or the decay of living corals is by no means definitely established as the cause of destruction of coral reefs. Although all reefs must stand against combined physical and biological destructive forces, it seems to be a rule that the mass of a reef at any time is well-balanced between increase due to its own growth and loss due to these destructive agencies.[6] The same may be said for the corals themselves.

Of the many organisms living in association with reef corals, some may be injurious, while others are harmless or even contribute to the consolidation of the corals. For instance, *Lithophaga* and other borers play an important role in coral reef destruction as they aid erosion by sea water. Yet it is highly questionable whether their occurrence leads to actual decay of coral colonies. The boring molluscs, such as *Lithophaga*, *Botula*, *Rocellaria* and *Petricola*, are found abundantly in coral blocks both dead and alive, as well as in limestone rock. However, they generally seem to bore into coral through its dead base, and then proceed upwards. It seems highly probable that the fleshy surface of the living coral prevents the penetration of these borers. This is apparently true of other boring organisms such as Algae and sponges.

Further, most of the large-sized borers, such as pedunculate cirripedes (*Lithotrya*), sea-urchins (*Echinometra*, *Echinostrephus*, etc.), chitons (*Acanthozostera*) and clams (*Tridachna*, *Arca*, *Lithophaga*, etc.), are always found on the rock surface of raised coral reefs or in dead coral blocks, practically never on living corals. Thus these borers are of special importance for breaking dead coral rocks into pebbles and sand.

Of small-sized borers, certain Euniciid worms and Sipunculids are occasionally found boring into living corals, but they are more abundant in dead coral rocks. Their effects are small as they are local in occurrence and their burrows are small. The number of worms to be obtained by breaking living corals is often remarkable. However, it is rather difficult to distinguish the species which actually bore from those living in tunnels made by real borers. In any case, these worms frequently settle on the healthy surface of living corals, massive ones in particular, or in silt-laden slits among partially dead calices, probably for protection and in search of food. Thus, they may gather relatively large quantities of fine sediment around themselves. Meanwhile they form their tunnels into the corallum, as they are sealed up by the growing coralline tissue. Such tunnels invariably run parallel to the surface of the colonies, so that their occurrence remains rather superficial, not being deeper than 2 cm. Sometimes short branchlets are bored upwards from these tunnels at intervals. These branchlets open to the exterior as a series of ostia, while they have blind ends in the deeper layers; these ostia are probably used as respiratory pores and for removing coral debris triturated by the worms. The tissue surrounding the ostia is invariably dead and is liable to accumulation of more sediment, and thus forms a foothold for the attack of surface-growing sedentary organisms, such as minute Algae, hydroids and Bryozoa. Empty tunnels formed by these worms are often occupied by pairs of the snapping prawn (*Synalpheus* or *Upogebia*). The dead area around the holes, and silt-laden depressions of living coral colonies, are sometimes covered by minute Algae, such as *Ceramium, Polysiphonia, Ectocarpus, Struvea, Herposiphonia,* etc., which spread over the living polyps. This covering appears to be injurious to living corals.

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[1] Gardiner, J. S., 1931. Coral reefs and atolls, London.

[2] Bertram, G. C. L., 1937. *Proc. Zool. Soc. London*, 1936: 1011-1026.

[3] Finckh, A. E., 1904. *Rep. Roy. Soc. London, Coral Reef Comm.*: 125-150.

[4] Otter, G. W., 1937. *Great Barr. Reef Exped., Sci. Rep.*, 1 (12): 323-352.

[5] Wood-Jones, F., 1910. Coral and atolls, London.

[6] Yonge, C. M., 1940. *Great Barr. Reef Exped., Sci. Rep.*, 1 (13): 353-391.

The sediment seems to be the most potent factor in causing the actual death of the coral polyp itself, and the encrusting organisms come next in importance. Most of the boring organisms weaken the structure of the coral and make it more prone to disintegration. The substratum liable to attack by boring organisms is, as would be expected, a clean rock surface, and not living coral, as they bore for protection only. There is no evidence that any boring organism is capable of killing coral polyps.

It is to be noted that there are some special groups of animals inhabiting living corals, showing a highly specialized structure in consequence of their peculiar symbiotic habit. Of these the crabs of the family Haplocarcinidae (*Haplocarcinus, Cryptochirus* and *Pseudocryptochirus*) are the most remarkable. These live in special galls or pits formed on living corals by the growth of surrounding polyps.[7, 8] Other examples are the acrothoracican cirripedes, such as *Lithoglyptes* and *Berndtia,* and the cirripedes belonging to the genera *Creusia* and *Pyrgoma.* The former penetrate into the coral skeleton through living polyp tissue; their boring action is apparently at first correlated with the upward growth of the polyp tissues, but does not extend into the corallum further than the surface layer (6 mm. thick).[9] The latter have no boring power, so they first settle down on the living surface of coral colonies and increase their length in accordance with the upward growth of the host, sometimes attaining a great length.[10]

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[7] Hiro, F. (= Utinomi, H.), 1937. *Palao Trop. Biol. Sta. Stud.,* 1: 137-154.

[8] Utinomi, H., 1944. *Palao Trop. Biol. Sta. Stud.,* 2: 687-731.

[9] Utinomi, H. Unpublished data.

[10] Hiro, F., 1938. *Palao Trop. Biol. Sta. Stud.,* 1: 391-416.

As the life of such associated animals seems to depend more or less upon the growth of host corals, the association is certainly indispensable for these commensals. Their effect upon the host corals is hard to determine, especially since there is a rather rigid host specificity. At any rate, they will eventually perish through the sealing up of their habitations by the growth of coral.

In addition living corals, especially the massive ones, are frequently much colonized by sedentary organisms, such as the bivalves *Pedum pedum* and *Beguina semiorbiculata,* the gastropod *Siphonium maximum* (= *Vermetus novae-hollandiae*) and the tube-dwelling polychaete *Spirobranchus giganteus.* Although they occur in no particular species of coral, their mode of life as well as their structure seems to be correlated with the growth of the substratum. Most probably lodge on the silt-laden dead part of depressions or crevices of the coral. Their establishment may be important in binding the crevices of the coral colonies together and thus in consolidation of the coral rock, although if dense they might tend to make the coral brittle.

Summarizing, the part which the coral-dwellers play in destruction is to be considered from two viewpoints, first as the agency causing the actual death of coral itself and second as the agency responsible for the disintegration of the underlying dead portion. The surface-growing organisms, such as Algae, hydroids and Bryozoa, may be considered as coming under the former heading. To this also belong some small borers like sponges, polychaetes and Algae, because their region of boring is superficial. Most of the coral- or rock-borers and certain of the molluscs and polychaetes which become established in crevices may be classified as of the latter category. True commensals seem to be indifferent in this respect. The death of coral is not always the direct cause producing the destruction of coral reefs.

CONSERVATION ASPECTS OF PACIFIC MARINE FISHERIES

By Robert C. Miller, Californian Academy of Sciences,
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In view of the prevalent shortage of food throughout much of the world, millions of persons appear condemned to permanent hunger unless new food resources can rapidly be developed. The oceans, covering seven-tenths of the surface of the globe, have a vast potential in this connection.

Since the Pacific, Indian and Antarctic Oceans constitute at once the most extensive and the least exploited of our remaining natural resources, it is imperative that they be exploited wisely and not simply despoiled to serve an immediate need.

The unhappy history of the California sardine affords eloquent testimony that a fisheries resource, however great, is not inexhaustible. For a period of years more than one-quarter of all the fish caught in the United States were California sardines, the annual catch commonly exceeding half a million tons. Suddenly in 1946 this fishery met with a decline of disastrous proportions, from which it has not yet recuperated.

On the other hand, the history of the halibut fishery in the north-eastern Pacific, demonstrates that a depleted fishery can be restored to a high, permanent level of productivity through scientific control.

Under unrestricted fishing, the total Pacific Coast halibut landings fell from 69,000,000 pounds in 1915 to 43,000,000 pounds in 1931. In 1930 a treaty was negotiated between Canada and the United States for joint study and management of the halibut fishery. As a result, the overall catch has been markedly increased above the 1931 minimum, and the catch per unit of fishing effort has more than doubled.

It is unlikely that a marine fishery can be entirely wiped out by overfishing. It can, however, be reduced to a low level of productivity, at which fishing becomes uneconomical because of the increased effort required to obtain a smaller catch. We have accordingly these two alternatives: through unrestricted fishing a fishery may become stabilized at a permanent, low level of productivity; or, through scientific management, it may be stabilized at a high, permanent level of productivity, yielding an optimum total return and a maximum return per unit of fishing effort.

At present a small part of the Pacific Ocean is being over-fished, namely the coastal waters of limited areas in the North Pacific. But by far the greater part of the Pacific is being under-fished. The vast South Pacific and the adjacent sector of the Antarctic yield only about 2 per cent of the commercial fish supply of the world. It is reasonable to suppose that this great area is potentially just as productive as any other comparable sector of the oceans. New Zealand is geographically in a position to become a headquarters for the exploration and exploitation of this fisheries resource.

Modern refrigeration and modern fishing boats and methods make it practicable to carry on fishing hundreds and even thousands of miles from the home base. The correlative development of pelagic fishing serves a two-fold purpose: it vastly increases the available supply of fish, and it reduces the strain on coastal fisheries by distributing the fishing effort over a greater area.

Coastal fisheries, at least out to the three-mile limit, are under the control of the nation along whose shores they are carried out. Pelagic fisheries present an entirely different problem, since the high seas are open to all nations on an equal basis. The investigation and regulation of fisheries on the high seas can only be carried out under international control. The International (Halibut) Fisheries Commission, and the International Sockeye Salmon Commission, established under treaties between the United States and Canada, have demonstrated the practicability of international fisheries undertakings. The successful management of a pelagic fishery involving nationals of a number of states requires the highest degree of international co-operation.

THE INDO-PACIFIC FISHERIES COUNCIL

By G. L. Kesteven, Singapore. (Abstracted by M. W. F. Tweedie)

The need for some effective means of co-ordination of fisheries programmes in the Indo-Pacific area has long been apparent. Detailed recommendations of the tasks they believed should be undertaken by some sort of international organization were made by certain UNRRA workers in Sydney in 1946. Their statement was adopted by a meeting of fishery workers convened in Singapore in January, 1947, and a proposal was made for the formation of a Council under the aegis of F.A.O., which was at that time working on a programme for the establishment of a world-wide pattern of such councils.

The Indo-Pacific Fisheries Council had its genesis in a meeting convened by F.A.O. for the purpose and held at Baguio in the Philippines in February, 1948. At this meeting a formal agreement was drafted and was subsequently submitted for acceptance to all Governments members of F.A.O. The Agreement provided that the Council should come into existence upon acceptance by five member governments, an event which took place on November 9th, 1948. The Council, therefore, is in existence although it has as yet no office bearers beyond an Executive Secretary provided by F.A.O. The appointment of office bearers and the further development of the Council's organization will take place at the inaugural meeting in Singapore commencing March 24th this year.

At Baguio four interim working committees were set up, named for hydrology, taxonomy, biology and technology. They were asked to propose a programme of work for the Council and to consider the limits within which it might most effectively operate. Some definitions submitted by the F.A.O. Secretariat were adopted and the Chairman of the Taxonomy Committee has written to a number of authorities in the field of bio-geography and sought their views on the delimitation of the Indo-Pacific area. An excellent response has been forthcoming and it is believed that a useful concensus of opinion on the limits of the area can be compiled from the replies.

The major proposal of the Committees was, however, that a survey should be made of the present status of fisheries knowledge and programmes in the area, embracing fisheries personnel, institutions, equipment, vessels and published literature, and that until such information was made available, proposals for co-ordination or development of national programmes would be premature. The Secretariat has accordingly been busy since the Baguio meeting in compiling such information with a view to establishing a register from which information can be supplied to the Council and Committees. Bibliographies for different sections of the region are being compiled and will be published, and publication of papers based on information collected for the Register is also contemplated.

Another item in which a good start has been made is the formation of a panel of specialists in various animal groups to assist in taxonomic work.

It is emphasized that while the Council's aim is to secure co-ordination and development of national fisheries programmes, extra-national activity is not, in general, contemplated unless, from time to time, any group of nations in the area may wish to carry out some part of their fisheries programme as a join effort. In such cases the machinery of the Council will, of course, be at their disposal.

The functions of the Indo-Pacific Fisheries Council are set out in Article III of the Agreement drafted at Baguio. In effect the interest of the Council is in every aspect of human activity concerned with the exploitation of fisheries resources, both marine and inland. Some idea of its scope is given by the designation of the four committees, hydrology, taxonomy, biology and technology, to which it has been suggested that a committee for socio-economics might be added. To this declaration of width of interest the Council must add the reservation that its scope is confined to fisheries and fisheries alone. Recognition of this principle leads the Council to seek the closest collaboration on a reciprocal basis with other international bodies concerned with related fields of study.

DIVISIONAL DISCUSSION ON FRESH-WATER BIOLOGY AND INLAND FISHERIES

GAME FISH PROBLEMS IN BRITISH COLUMBIA

By W. A. Clemens, Department of Zoology, University of British Columbia, Vancouver, B.C., Canada

[*Abstract*]

The game fishes of British Columbia are almost exclusively members of the family Salmonidae. In the lakes and streams there are the rainbow trout, *Salmo gairdneri,* the cut-throat trout, *Salmo clarkii,* the introduced brown trout, *Salmo trutta,* the Dolly Varden char, *Salvelinus malma*, the introduced speckled char, *Salvelinus fontinalis,* and the Great Lakes trout, *Cristivomer namaycush.* In addition, in the northern portion of the province, there occurs the grayling *Thymallus signifer,* and in the southern portion the introduced black basses *Micropterus dolomieu* and *M. salmoides.* In the coastal waters the spring salmon *Oncorhynchus tshawytscha* and the coho salmon *O. kisutch* provide a very popular sport fishery.

As in practically all fisheries the main problem is that of production in relation to fishing intensity. The sport fisheries of the inland waters fall under the jurisdiction of the Provincial Game Commission, and this organization, in co-operation with the Department of Zoology of the University of British Columbia, has initiated a programme of investigation. The main problem under study is the relation of predator and competitor fishes to the production of game fishes.

The ocean fisheries are supervised by the Dominion Department of Fisheries, and certain investigations have been carried out by the Fisheries Research Board of Canada. While these have been concerned primarily with commercial aspects, they have provided information relative to the sport fisheries. The programme has involved tagging procedures, enumeration of adults proceeding upstream and young migrants travelling downstream, foods taken while in the sea, and age determination.

CONTROL OF THE PIKE-WHITEFISH TAPEWORM IN CENTRAL CANADA

By K. H. Doan, Central Fisheries Research Station, Fisheries Research Board of Canada, Winnipeg

Introduction

Value of Whitefish

Commercial catches of whitefish, *Coregonus clupeaformis,* in the provinces of Manitoba, Saskatchewan, Alberta, and in the North-west Territories together amount to 12-15 million pounds annually, worth about two million dollars to the fishermen and five million dollars as marketed. It is one of the most valuable of the freshwater food fishes.

Marketing Difficulty

Most of the Canadian fish production is exported, and nearly 90 per cent of the whitefish goes to the United States. Its importation is under scrutiny by the Pure Food and Drug Administration and must conform to standards for quality. Unfortunately some lakes in Central Canada produce whitefish too heavily infested with intermediate stages of the tapeworm *Triaenophorus crassus* to meet the quality standards. Refusals of admission led to considerable loses for Canadian shippers, and international relations were not helped by the absence of some quality control before the fish were exported from Canada.

Inspection and Research

Following several years of friction over the whitefish situation, the Prairie Provinces Fisheries Investigation Committee was formed jointly by the Dominion Government and the governments of the three provinces, and in 1943 advocated a Canadian inspection of all whitefish produced for export from those provinces. This inspection came into practice in the following year.

The Committee also pointed out the necessity of more research with the objective of breaking the life-cycle of the parasite and effecting a cure more basic than inspection. The Central Fisheries Research Station was established in 1944 with this objective as one of its chief functions.

LIFE HISTORY OF TRIAENOPHORUS CRASSUS

Although some earlier work on the tapeworm *T. crassus* had been done, most of the credit for recent researches on its life history must go to Dr. R. B. Miller who conducted his investigations for the Alberta Department of Lands and Mines and for the University of Alberta.

Adult tapeworms live in the intestines of pike, *Esox lucius*, and in the spring they die after having produced many eggs which hatch in the water into small, ciliated coracidia. A young worm may be swallowed by a water flea, *Cyclops bicuspidatus*, and, if the water flea is eaten by a white fish about ten days later, the parasite penetrates the fish's stomach wall and lodges in the flesh, usually above the ribs. Here it lies within a sac, and, with its waste products, forms an object of aesthetic distaste to a prospective human consumer. If within three years the whitefish is taken as food by a pike the worm is released from its cyst and attaches itself to the inside of the pike's upper intestine and grows to maturity. The pike is the only known host of adult *T. crassus*, but several coregonines and related fishes may harbour the second intermediate stage.

QUALITY CONTROL

Lake Surveys

The degree of parasitization of whitefish varies in different lakes, so one of the first steps in quality control was to survey the whitefish in each lake. About 200 surveys were made in the first year of operation, i.e., to the end of 1945, by provincial personnel, and analyses of all the reports by a federal whitefish inspector showed that if about three million pounds of the poorer quality whitefish were removed from production the overall picture would be considerably brightened. The provinces accordingly closed the poorer lakes, and the volume of rejections by the United States showed a gratifying shrinkage.

Whitefish Inspection

The surveying of lakes of origin has not completely eliminated the production of nonacceptable whitefish, however, so in the near future all shipments of whitefish will be inspected before they leave Canada.

The testing of a fish for worm content involves its complete destruction insofar as its ordinary form and market value are concerned, so satisfactory tests using a minimum of fish were desired. From arbitrary standards used in earlier testing, statistical methods have now been developed employing sequential analysis with a maximum of confidence in the inspection and a minimum of time and samples.

Candling

Candling is the term applied to the process of viewing a whitefish or its fillet by transillumination, the same as in egg inspection. It has been applied only on a small scale, because the tapeworm makes a shadow in the flesh only when close to the surface, so that deeper cysts cannot be detected. Worms which can be thus seen are taken out by a knife or forceps, and the fillet may then pass inspection. The experimental testing of various colours and intensities of lights at the University of Alberta and elsewhere and the testing of X-ray equipment at the Pacific Fisheries Experimental Station, have not found a satisfactory method of candling whitefish.

Size Selection

In some lakes, but not as a general rule, whitefish of specific size ranges—for instance, all whitefish over four pounds in weight—would pass inspection. The sorting out of such fish, and the elimination of the undesirable fraction of the catch, have presented administrative difficulties that would make this method generally inapplicable.

Area or Depth Selection

In some lakes the whitefish population is obviously not homogeneous, because extensive differences in whitefish infestation exist in different areas or at different depths in the lake. Broadly speaking, whitefish from shallow parts are of inferior quality to those from deep portions of a lake, and this principle has been applied in the management of a few waters.

Break-Life Cycle

The surveying of lakes for overall quality, inspection on the way to market, candling, and selective fishing, are only temporary expedients in the elimination of poor quality in whitefish. Full use of all production capacity should be the aim, and this cannot be attained unless the tapeworm is severely reduced or eliminated in the lake itself. This can be effected only by breaking the life cycle.

Control Points in Life Cycle of Tapeworm

Destruction of Coracidia

Only for a few days after hatching from the egg does the young tapeworm lead an existence apart from some host. This fact led Miller to test various agents for their possible toxic effect upon free-living coracidia. It was discovered that acidulation of water to a point more acid than normally found in natural lakes caused failure in the worm's osmotic control, with the result that it swelled up and burst. A practical demonstration of this, using several tons of sulphuric acid in a lake, showed natural waters and bottom sediments to be so strongly buffered that the acid's effect was extremely temporary and the coracidia suffered no serious harm.

The search for coracidiacides has continued. Several have proved efficient in dilute concentrations, but are still too expensive for extensive application.

Destruction of Water Fleas

The first intermediate host of the pike-whitefish tapeworm, the microcrustacean *C. bicuspidatus,* is so cosmopolitan that its eradication or control has been regarded as one of the larger impossibilities of the whole programme, and has not been attempted.

Destruction of Secondary Intermediate Hosts

The second intermediate stage of *T. crassus* has been found not only in whitefish but also in lake trout, *Cristivomer namaycush,* Arctic grayling, *Thymallus signifer,* inconnu, *Stenodus leucichthys mackenzii,* round whitefish, *Prosopium cyclindraceum,* Oregon whitefish, *P. oregoni,* and various species of cisco or tullibee, *Leucichthys.* In most of these the tapeworm is believed to be an accidental or occasional parasite. In tullibee, however, it flourishes with success.

Tullibee. That the tullibee has proved such a successful host is perhaps attributable to two reasons. In the first place, tullibee feed upon plankton all their lives, not just when young or only incidentally as do the other secondary intermediate hosts. They, then, are almost certain to receive a fresh dose of *Triaenophorus* every spring when the water fleas, their food, are infected. Secondly, tullibee do not generally grow to the large size attained by whitefish, and so serve as suitable food for pike all their life. The belief that *T. crassus* would be more aptly named the pike-tullibee tapeworm is strengthened in the fact that in lakes containing *C. bicuspidatus,* pike, whitefish and no tullibee, the whitefish are free of the tapeworm. Tullibee must be present as a tapeworm reservoir, the overflow from which may infest the whitefish.

This has led the Alberta Government to sponsor an intensive fishery for tullibee in Lesser Slave Lake, where mink ranchers have created a great demand for fish for feed. In but a few years this 60-mile lake was producing 4½ million pounds of tullibee annually. This exploitation removed practically all the older fish, and the fishery became dependent upon two-year-olds whose growth rate had increased remarkably. More significantly, the decline in infestation with *Triaenophorus* was so great in the tullibee that its effect was soon reflected in the quality of whitefish. These, from having been of poor quality, improved so much that they were highly approved for export.

The province of Saskatchewan has taken steps towards tullibee control in a demonstration lake. And in Manitoba consideration is being given towards ways and means of exploiting tullibee in Lake Winnipeg, the seventh largest lake in North America.

Destruction of Adult Host

Pike, the only host of the adult stage of *T. crassus,* offer interesting possibilities of control. Being piscivorous and solitary of habit they are usually not as abundant as the foraging tullibee. They have no great commercial value, and are heartily disliked by fishermen because of their destructive action upon nets. On the other hand, they are one of the world's most successful fishes in penetrating and maintaining themselves in the North Temperate Zone, and thus must rank as worthy adversaries in attempts to reduce their abundance.

(a) *Manipulation of water levels.* Pike spawn in the spring, usually in May and June, in grassy shallows immediately after the ice goes out. These shallows, often in bays or along marshy creeks, become warm quite rapidly under the spring sunshine, and pike eggs hatch in about ten days. Miller has suggested the possibility of raising the lake level in early spring by a dam at the outlet, allowing the pike to spawn, and then to destroy the eggs before they hatch by exposing them to a sudden lowering of the water. Unfortunately, spring water levels are usually so high, and normal lake outlets so restricted and not permitting of sudden reductions in lake levels, that no suitable situation has presented itself to investigators for test.

(b) *Poisoning.* The use of poisons in fish cultural operations has met with some success. Some form of derris root (rotenone) has been employed mostly, for the complete or partial elimination of fish populations.

In Alberta rotenone was distributed at selected localities about a lake where there were believed to be congregations of pike. Although solitary hunters, pike do come to favoured places for spawning, and usually seek shallow, weedy places as feeding and sunning stations. Miller effected a considerable reduction in pike by spot poisoning, and brought about some improvement of quality in tullibee. But enough pike escaped with their lives to carry on the tapeworm cycle, and the improvement in tullibee quality (applicable to whitefish) was not complete enough to term the experiment an unqualified success.

The complete poisoning of a lake for the elimination of all fish, with screening to prevent re-entry, and the planting of whitefish eggs or parasite-free fish, could logically give good results. But the practicality of poisoning large lakes and maintaining barriers rules this out of the question from the viewpoint of cost.

Techniques in malarial mosquito control have been developed which are based upon spreading poison upon vegetation *before* an expected flooding, and enough poison remains *after* high water and the influx of breeding stock to make the submerged vegetation lethal to young mosquitoes. A possibility exists of adapting this to pike control. Favourite grassy spawning grounds could be posioned in the autumn when the water was at low level. The ideal poison would be one which clung to the vegetation and lost little potency overwinter, so that when the area was submerged in the spring all pike eggs and fry would be destroyed when they came in contact with the poisoned grass.

(c) *Trapping.* Pike often travel out of a lake for their spawning migration. This takes them through narrow channels into connecting lakes or bays or up or down tributary streams. Stationary traps in operation each spring would intercept a large proportion of the adult fish, and they could be removed from the lake. Owing to difficult travelling conditions in most areas at break-up time, most traps would require a resident operator. In Manitoba a wood and wire trap was operated in a small stream used by pike in the spring, and 10,000 pounds were caught and marketed in two weeks.

(d) *Netting.* Netting of pike may be accomplished under the stimulus of commercial fishing, i.e., for direct profit, or under various guises, such as catching them to feed fur animals. They are not a fish preferred by the net fisherman under ordinary circumstances so it is unlikely if any great reduction in their numbers can be accomplished without special inducement.

Saskatchewan has made some effort to take pike with special crews employed for the purpose, but it is doubtful if enough were caught—although the total was several thousand pounds—to bring about any change in the quality of whitefish in the lake.

For four years a pike-netting demonstration has been operated on a small lake in northern Manitoba, and certain conclusions are now evident.

THE HEMING LAKE EXPERIMENT

Heming Lake

To test the efficiency of netting pike as a method of reducing whitefish infestation, a small lake was selected in 1945 and subjected to fishing each spring and early summer. Heming Lake contained a population of whitefish heavily parasitized by *Triaenophorus*; its small size of 588 acres offered reasonable hope of control by a small field party; it was towards the headwater of a drainage system, so that tributaries were few and small; it was unexploited by other fishermen, so that experimental operations represented total fishing effort; it was located on a railway; there were a limited number of marshy bays for the use of pike. In addition, a small cabin was made available through the courtesy of the trapper.

Heming Lake is situated in the province of Manitoba at approximately 54° 53′ N. lat. and 101° 7′ W. long. It is 18 miles south of the town of Sherridon, is three miles in length and from one-quarter to one-half mile in width, and lies in the headwaters of the Grass River, a tributary of Nelson River which flows into Hudson Bay. There are eight main bays with muskeg shores and muck bottom, depths of water up to 6 feet, and with a fringe of emergent and considerable submerged vegetation. The remainder of the lake has little vegetation, has shores of igneous rock and sand, and a bottom of inorganic silt covered with decayed organic matter. Depths do not exceed 16 feet, the water is acid and brownish, and visibility is about 6 feet. Heming Lake is ice-covered for six or seven months each year.

There are two main tributary streams. One is deep and slow moving, passing through a grassy muskeg where it enters the lake; it is here that most of the pike gather to spawn. The other is rapid and shallow, does not attract pike, and runs of fish are effectively blocked by a beaver dam 5 feet in height. The outlet stream flows to another lake about two miles distant, has four rapids, but offers no serious barrier to the passage of fish. The outlet of Heming Lake was screened in 1945, but the wire netting rusted away within a few months. Subsequently, beavers erected a dam below the outlet, so that most fish are blocked from coming up to Heming Lake.

Netting Operations

Intensive netting for pike, using gill nets of various sized meshes about the lake shore, and hoop nets[1] at the mouth of the favourite spawning stream, has been conducted in May and June each year from 1945 to 1948. Hoop nets proved relatively inefficient at other locations. Whitefish were taken in gill nets in the main body of the lake, and could be caught at all seasons of the year.

Pike

(a) *Catch*. The catch of pike in Heming Lake varied during the different years partly because of changing availability of fish and partly as a reflection of the total effort expended in their capture. About 2 pounds per acre were removed each year, and this was accomplished with least effort when the project was started in 1945. In no year subsequent to 1945 were pike taken as easily by hoop nets at the spawning stream in May and June, but the decrease was not regular (Table I).

TABLE I.–CATCH OF PIKE IN HEMING LAKE, MANITOBA, BETWEEN 1945 AND 1948, AND DATA ON WHITEFISH INFESTATION

	1945	1946	1947	1948
Pike caught, number	563	571	931	705
Pike caught, pounds per acre	2·25	1·8	2·31	1·95
Pike caught, per cent 18 inches in length and over	82	58	48	53
Pike caught, pounds per hoop net per night at spawning stream in May and June	18	3	7	8
Whitefish examined, number	273	125	161	278
Cysts, number per 100 whitefish . . .	528	327	322	353
Cysts, number per 100 pounds of whitefish	290	156	168	196
Cysts, greatest number in one whitefish .	99	33	17	32

The years 1945 and 1948 brought similar spring break-ups of the ice and fishing results are more comparable between them than under fishing conditions in the intervening years. From the last week in May until the middle of June, weekly catches were about half those of the immediately previous week, and fishing in 1948 produced about half the return for the same effort that it did in 1945 (Table II). This rate of decline did not persist past the spawning season. It may be concluded that Heming Lake had a pike population in 1945 at least twice that of 1948, and the yield in the years between indicated the reduction had been even greater.

TABLE II.–AVERAGE WEEKLY HOOP NET CATCHES OF PIKE IN THE SPAWNING STREAM AT HEMING LAKE, MANITOBA, IN POUNDS PER NET PER NIGHT

	May 22–31	June 1–7	June 8–14	June 15–21	June 22–30
1945	49	27	19	5	
1948	27	13	6	7	4

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[1] Each net was provided with four oak hoops; the first two were 5 feet in diameter, and the last two were 4 feet. There were two tunnels and two 20-foot wings seamed in 9 thread rope. Wings were of 4-inch mesh of 9 to 12 thread seaming twine. The net was made of from 12 to 15 thread seaming twine, and around the hoops of about 36 thread twine. From the first hoop to the first tunnel it was 4-inch mesh, to the second tunnel it was 3¼-inch mesh, and the pot was between 2¼- and 2½-inch mesh. The pot was closed with a draw rope, but greater convenience in emptying the pot was obtained by using a dip net through a laced slit in the side of the pot. Each hoop net was tarred. No leads were used.

(b) *Biology.* The netting programme brought about a reduction in the average size of pike, presumably by removing larger fish more efficiently than smaller ones. Four-fifths of the pike caught were over 18 inches in length in 1945, but only about one-half exceeded this size in later years (Table I). This reduction of larger pike is important, because they are better able to consume whitefish and propagate the tapeworm.

In the spring pike up to 1 pound ate mostly trout perch, *Percopsis omiscomaycus,* in the neighbourhood of the spawning stream, as trout perch were also making a spawning migration. Elsewhere in the lake they fed upon other small fishes also. In the early autumn and winter larger pike depended upon whitefish for their food, as well as other fishes of larger size.

Spawning occurred in the grassy edges of one of the tributary streams, became general when the water temperatures reached 40° F., usually in the latter part of May, and was concluded by the time the water was 45° F., early in June in most years. The water temperature in the shallow flooded areas sometimes was 10° higher than in the stream itself, and the lake proper was still covered with ice.

Pike became mature at the beginning of their third year of life, and some were about 12 inches in length. These were too small to be caught effectively by the hoop nets. Female pike produced from 4,000 to 7,800 eggs per pound weight of fish, and on a body weight basis the greatest yields were from five- and six-year-old fish weighing 2 to 3 pounds.

In Heming Lake pike attained fork lengths of 8, 13, 17, 19, 21, 24, 30 and 34 inches in their second to ninth years, respectively.

Whitefish

(a) *Catch.* Only whitefish 13 inches and over in length have been considered with reference to infestation, because none smaller are customarily commercially marketed. The removal of a few hundred each year has apparently made no effect upon their availability in Heming Lake. They are, perhaps, a little smaller now than in 1945.

(b) *Infestation.* When the lake was first examined in March, 1945, the whitefish averaged 289·6 cysts of *Triaenophorus* per 100 pounds of whitefish. This remained unchanged that year, but the following year only about half as many were found (Table I), and there has been no further improvement in quality based on annual averages of samples. The infestation was cut in half again by the end of the summer of 1947, but only proved to be temporary, not greatly influencing the average for the year. The greatest number of cysts in one fish was 99 in 1945, but has not been more than 17 in any year since then. These heavily parasitized whitefish were exceptional individuals.

The incidence of infestation increased in the fish with each year of age and reached a maximum at age 8, after which there was some decline. The greatest rate of increase in parasitization occurred from age 4 to age 5.

(c) *Biology.* Age-frequency distribution of 439 whitefish taken in 1945 showed bimodality at five- and nine-year classes, at average lengths of 13·8 and 15·3 inches, respectively. The nine-year-olds have not continued in importance since then. After the fifth year length and weight increases became slower than in earlier years of life. It was in their fifth year that some whitefish matured, and the remainder did so a year later; in general, males matured a little earlier and lived longer than did females.

In the spring whitefish foraged through Heming Lake, and less than 10 per cent had not been feeding. There were no consistent differences in the food taken by fish of various sizes and at this time of year they had a more varied diet than in the autumn or late winter. Their slow growth is possibly related to the meagre bottom fauna, 0·5 c.c. per sq. ft., but they ate what was available without any marked selectivity. That they must ingest the occasional *Cyclops* is evident from the parasites they bear, but none were seen during the analyses of whitefish stomachs. Indeed, it is remarkable that they are not even more heavily infested by accidentally consuming parasitized microcrustaceans which were present in the lake in numbers exceeding 6,000 per c.m. in June, 1948, and 43 per cent of these carried procercoids of *Triaenophorus*.

Summary and Conclusions

1. Whitefish, one of the most valuable commercial fishes in Central Canada, sometimes suffers difficulty in marketing owing to the undesirable presence in the flesh of an intermediate stage of the tapeworm *Triaenophorus crassus*.

2. The life history of the tapeworm is known, and involves a microcrustacean and pike, besides whitefish or tullibee.

3. Quality control has been instituted by surveys of lakes producing whitefish, by inspection of shipments, and by selective fishing.

4. Research into methods of breaking the parasite's life cycle have involved poisoning coracidia and pike, and intensive netting of tullibee and pike.

5. An account was given of the latter, where pike were attacked upon a basis of knowledge of their habits and those of whitefish, but the pike population could not be reduced by netting to a level low enough to effect more than a 50 per cent improvement in whitefish quality.

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FACTORS AFFECTING THE FRESHWATER DEVELOPMENT OF PACIFIC SALMON IN BRITISH COLUMBIA

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The five species of *Oncorhynchus* which inhabit British Columbia waters all spend part of their lives in fresh water. Although the sockeye (*O. nerka*) frequently, and the coho (*O. kisutch*) occasionally, remain in this environment throughout the life-cycle, freshwater existence is usually a temporary phase, varying in length in different species and different individuals. The minimal period is exemplified by pink salmon (*O. gorbuscha*) and chum salmon (*O. keta*). The mature adults of these species commonly enter fresh water in the autumn, deposit their eggs almost immediately, and the resulting young fish make their way to sea in the following spring. Many spring salmon (*O. tshawytscha*) have an equally transient freshwater phase as regards the early development although the adults frequently enter the rivers some weeks or even months before spawning takes place. Longer periods are spent in fresh water by other spring salmon, by cohos and by sockeyes. In these cases the young fish remain in streams or lakes until their second spring or, in the case of some sockeyes, even longer.

Although the period spent in fresh water usually constitutes only from about one-half to one-sixth or less of the total life-cycle, the mortality which occurs during this phase is of much greater magnitude. In a number of experiments in British Columbia the percentage mortality (based on number of eggs available for deposition) between the time when the adults approach the spawning grounds and the time when the young fish migrate seaward has been determined as follows: Chums, 92·7 to 99·65; Pinks, 76·2 to 99·15; Coho (ca.), 98 to 99; Sockeye, 97 to 99.[1] If on the basis of these figures, a freshwater mortality of 98 per cent be regarded as average (at least for certain species) it is obvious that a variation of only 2 per cent in the lethal effectiveness of the environment would be sufficient to either double the production of seaward migrants or eliminate them entirely. In view of the considerable differences which can be observed from year to year in the physical and biological conditions obtaining in salmon-producing streams and lakes, the freshwater environment can be suspected on general grounds of being a potent cause of fluctuations in the abundance of mature salmon.

THE FRESHWATER HABITAT

Nearly all the permanent streams and rivers of British Columbia which are accessible to fish travelling from the sea are occupied to some extent by one or more species of Pacific salmon. Most of these watercourses can be grouped roughly into two categories, namely (1) streams of small or moderate size, the volume of which is closely associated with rainfall and hence tends to be high in autumn and early winter and much reduced in late summer, with accompanying high water temperatures, (2) streams and rivers, often of moderate or large size, which receive contributions from glaciers and hence maintain a relatively large flow of cool water during the summer, with reduced volume in late winter. In the larger watersheds, streams of both types frequently occur. Common characteristics of salmon streams in general are stretches of rapid or fairly rapid water with areas of gravelly or stony bottom. In the case of the sockeye, many fish spawn on lake shores and lakes are the preferred habitat of the young fish.

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[1] By R. E. Foerster, A. L. Pritchard, F. Neave *et al.* Summarized by Pritchard (1947), except for recent unpublished results obtained by Pacific Biological Station.

Factors Causing Mortality in Fresh Water

Various more or less specific causes of mortality can be recognized. Since many of these are inter-related and since controlled experiments on the limits of tolerance of salmon to various physical and chemical conditions are largely wanting, quantitative values can rarely be assigned to single factors. These factors represent the various and varying pressures exerted by a restricted and changeable environment rather than a fixed pattern of separate risks. Field observations permit the following remarks.

Chemical factors do not ordinarily appear to limit survival to a marked degree. Quantities of dissolved gases and pH values in lakes and streams are usually well within the range of toleration and present no barriers to free movement. Reduced oxygen is probably an important immediate cause of mortality among buried eggs and alevins, or among young fish trapped in pools, but such losses can often be associated with failure in quantity rather than quality of water. Instances of losses caused by pollution from sawdust and industrial effluents have been reported but such conditions are not widespread at the present time.

Physical factors, on the other hand, exert very marked effects on the freshwater phases of salmon. The distribution of eggs is of course determined to a large extent by the availability of favourable types of bottom. Typical spawning ground consists of clean gravel and stones, the smaller elements of which can be washed out, so that the eggs settle in crevices at a considerable distance below the original surface. They are then covered with fine gravel, the particle size and hence the porosity being directly related to the discharge. Salmon will at times deposit eggs in the absence of any movable gravel, among relatively large stones or boulders, even when these are resting on bedrock. It may be presumed that in the latter instances eggs are more vulnerable to the attacks of predators and to the danger of being washed away. Potentially suitable spawning grounds are frequently non-utilizable, through the presence of physical barriers to migration of the adults. These barriers may be permanent, temporary or intermittent in their action and may take the form of waterfalls, dams, log jams or rock slides. A classic example of the disastrous effects of an obstruction is provided by the (man-made) rock slide at Hell's Gate on the Fraser River which largely destroyed the reproductive efficiency of the big sockeye run of 1913. On a smaller scale, physical barriers often prevent the most effective use of the freshwater environment.

The effects of obstructions are very frequently linked with fluctuation in the available water supply, which also has other important consequences. Wide variations in discharge are characteristic of most British Columbia salmon streams and are most pronounced in areas where the rainfall tends to be seasonal and where through the steep rocky nature of the watershed and/or the removal of forest cover, the run-off is relatively unchecked. In such streams, barriers which are more or less ineffective when water levels are high, are frequently insurmountable at times when the discharge is small. In fact fish may be prevented from entering streams or reaching spawning grounds by mere lack of a sufficient volume of water for them to swim in. Pink and chum salmon appear to be particularly affected by such conditions, although other species are also hampered at times. In general, a large volume of water at the time of entering fresh water and during the ensuing period of spawning exerts a favourable influence on reproductive efficiency. This factor indeed can sometimes be recognized as a dominant influence in determining the numbers of adult fish which return in the cycle year (see Fig. 1).

Cohos, which tend to enter streams after water levels have risen and which are better capable of surmounting obstacles, are probably less influenced by variations in discharge at and immediately before spawning time. In this species, however, the young fish remain in streams for a year after emergence from the gravel and their survival appears to be determined to a considerable degree by the extent of the summer shrinkage of the freshwater environment (Fig. 2). This reduction in the water supply results in the trapping of fish, increased vulnerability to predators and restriction of feeding grounds and movement.

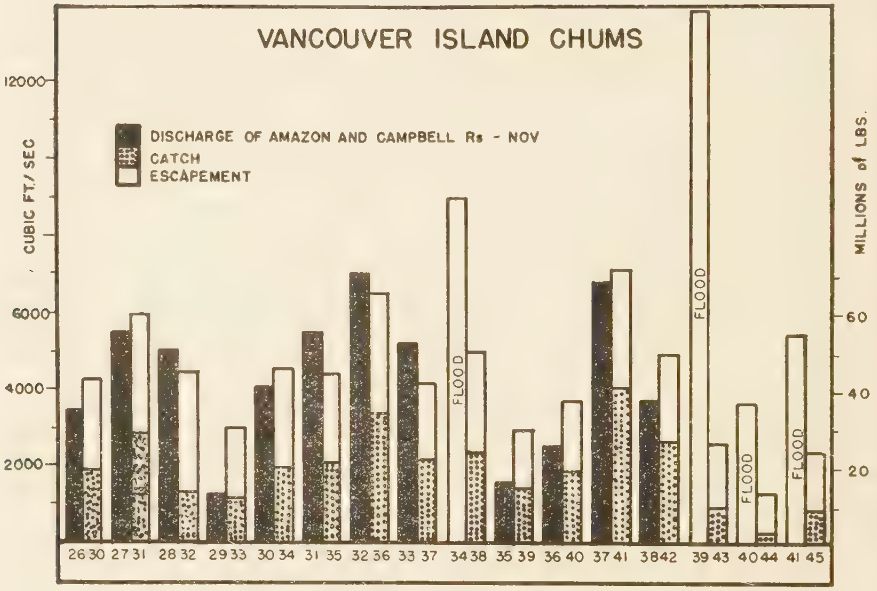

FIG. 1.—The graph shows total combined mean discharge for Amazon and Campbell rivers for the month of November from 1926 to 1941. These figures are compared with the chum salmon runs four years later, this being the usual length of the life cycle of this species. The years in which exceptionally severe winter floods occurred are indicated. Note reduction of population in these instances.

While a large volume of water at spawning time has been designated as a desirable condition, its effect can be nullified or modified by subsequent variations in discharge. Prolonged lowering of the water level in late winter or spring sometimes dries up the spawning beds and prevents emergence of the fry. Considerable destruction from this cause has been observed on the east coast of Vancouver Island, especially among chum salmon alevins.

Severe floods during the period of incubation can also be very destructive. The force of the water at times tears up spawning beds, removing gravel and eggs. Silt carried by flood waters is deposited in different places and affects the penetration of water into the underlying gravel. Silting up of redds has been considered to be a major cause of mortality by Hobbs (1937) and others. It is possible that silting caused by heavy floods may render gravel beds unsuitable for occupation in succeeding years.

The general destructive effect of floods appears to be exemplified by the production of seaward-travelling chum migrants at Nile Creek, Vancouver Island. Production in the spring of 1946 after a moderately favourable winter was 3 per cent of available eggs. In 1947 and 1948, following several severe floods in each instance, production as measured by counts of descending fry fell to 0·44 per cent and 0·38 per cent. In 1949, after a spawning season characterized by a relatively high general water level, but without subsequent severe floods, production rose to 6·03 per cent.

Rivers derived in part from glaciers commonly carry much fine silt during a considerable part of the year. The suspended material does not ordinarily prevent the migration of salmon (although such an effect has been reported to us on at least one occasion) but it is believed that in general the parent fish tend to seek tributaries and side channels which are relatively free from silt for the deposition of the eggs.

Temperature, as is well known, plays an important part in determining the length of the incubation period and presumably influences the production of food supplies, particularly the planktonic forms on which young sockeyes feed. The freezing of water supplies, and even the eggs themselves, is believed to be a cause of mortality in some inland localities under severe winter conditions. High summer temperatures are seldom directly lethal in natural salmon streams but undoubtedly create unfavourable conditions on occasion. Increased mortality has been noted in the Columbia River system (Fish, 1948) at temperatures above 16° C. Temperatures up to 22° or higher frequently prevail in certain British Columbia salmon streams in late summer.

Biological factors in the freshwater environment are linked in various ways with the conditions already mentioned.

Predation, in some degree, accompanies all phases of the freshwater existence of salmon, the adult fish being taken by birds and mammals and the eggs and fry by a variety of terrestrial and aquatic piscivores. Low water conditions favour attacks, at least by such terrestrial predators as birds, mammals and snakes. Predation is especially serious during the period from the emergence of the fry until the escape of the young fish to sea. Foerster (1938) found a mortality of about 89 per cent in young sockeye during a year's residence in fresh water at Cultus lake. This loss was mainly attributed to predation by other fish and subsequent removal of a proportion of these predators from the lake resulted in increased survival of sockeyes (Foerster and Ricker, 1942). Cameron (1941) found a loss of roughly 50 per cent in marked pink salmon fry descending a short distance to the sea (McClinton Creek, Queen Charlotte Islands). Marked chum salmon fry in Nile Creek, Vancouver Island, have shown loses of 40 per cent in descending distances of 300 to 400 yards in two to three days. While such figures should not be regarded as being necessarily typical, they indicate that predation is a very serious factor at this stage of the life history.

Competition between Pacific salmon and other species of fish for available food is a factor concerning which almost nothing is known, although it is evident that such rivalry may be of importance in view of the limited and variable food supplies of the freshwater habitat. Intraspecific competition of this type appears to be demonstrated in sockeye lakes, where smaller populations of young fish have shown better growth than large populations (Foerster, 1944). Any factors which tend to reduce growth of small fish are of course likely to expose the latter to more prolonged and intensive predation.

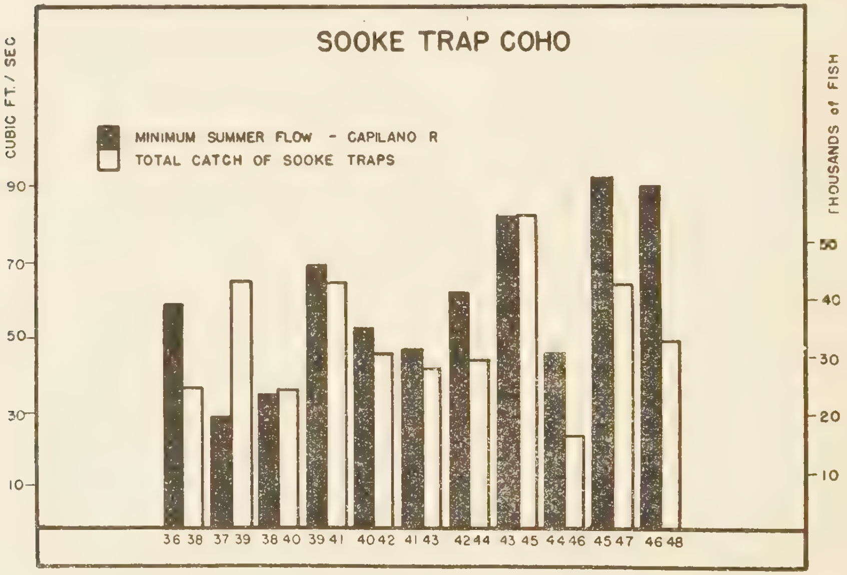

FIG. 2.—The catch of cohos by fixed gear is compared with minimum summer flow in a representative stream two years previously, this being the interval between the freshwater yearling stage and the return of the adults.

Another type of competition which is well recognized although difficult to measure in terms of percentage mortality, is between adult salmon on the spawning grounds. Eggs which have been deposited are frequently dislodged or otherwise interfered with by fish of the same or another species subsequently using the same site. Also, when spawning adults are numerous at the same time, the best sites may be fully occupied and some fish will have to utilize less favourable locations. This sort of competition is a function of the number of fish, the extent to which they synchronize in time of arrival, the size of the spawning beds available and the condition of the fish when they arrive. It is evident that the volume of water will have a great effect on the extent of spawning territory and on the ability of the fish to distribute themselves in a favourable manner. Further, when the fish arrive in an advanced condition of maturity, as is often the case with chums, they will have little time in which to seek upstream locations or to wait for better conditions. Consequently, local crowding can occur near the mouths of streams which are only sparsely occupied elsewhere.

Bacterial and fungal infections are common in adult salmon in fresh water. They are doubtless responsible for some losses, particularly among fish such as some sockeye and spring salmon which remain in fresh water for an extended period (and frequently under unfavourable conditions) before spawning (see under "Temperature"). *Saprolegnia* is usually regarded as a secondary infection, attacking dead, broken or abraded tissues and eggs. It seems probable, however, that in natural redds, where dead eggs are not removed, the development of this fungus may have serious effects on neighbouring and previously healthy eggs. Clusters of eggs matted with *Saprolegnia* can frequently be dug from stream beds and serious loss from this cause is suspected to occur in certain years.

IMPORTANCE OF FRESHWATER FACTORS AS MEASURED BY ADULT POPULATIONS

If each of the several causes of freshwater losses is lessened, within limits, by increased flow, discharge should give some measure of freshwater survival. Again, if for Pacific salmon the freshwater losses are predominant in the life cycle, adult populations should vary in size with freshwater discharge at periods when losses are greatest or most variable.

Figures 1 to 4 present cases in which a marked correlation appears to exist between the volume of the freshwater environment and the numbers of adult fish subsequently returning from the ocean. Since data for individual salmon streams are not usually available, ecological areas have been used—the first two being portions of the lower British Columbia coast and the last a centrally situated district. Population sizes of cohos (Fig. 2) are considered to be indicated by the annual catches made by traps located at Sooke (S.E. end of Vancouver Island). These operate in the same place and manner each year. For pinks and chums, figures for the total population (catch plus escapement) have been used. Catches are taken from fishery statistics. Numerical estimates of escapements have been approximated by using inspectors' reports in conjunction with conclusions formed as to the ratio of catch to escapement in certain years, based on tagging experiments. Discharge values for Figures 1 and 2 are provided by one or two streams in the area for which complete data are available. In the Central area, where no such complete discharge records exist, precipitation figures have been substituted. The presence in this area of glacial rivers which do not fluctuate with precipitation in the same manner as non-glacial streams, introduces a potential error.

The degree of reproductive success achieved by a spawning escapement can be represented by an "index of production", $\frac{S_n \quad C_n}{S_o}$ where S_n and C_n are spawning escapement and catch of the offspring run, and S_o is the parent escapement. By comparing the index of production with discharge (or precipitation) the size of the parent spawning escapement is taken into consideration. This could certainly be expected to influence the size of the offspring population and an improved correlation is shown in Figure 4 when "index of reproduction" is substituted for "size of offspring population". For chum salmon in the Vancouver Island area, however, no such improved correlation is evident. The apparent unimportance of the size of the spawning population (within the limits observed) probably reflects the sensitivity of this species to physical conditions. Average survival to the fry stage appears to be so low that relatively small changes in percentage mortality probably outweigh considerable fluctuations in the number of eggs initially available.

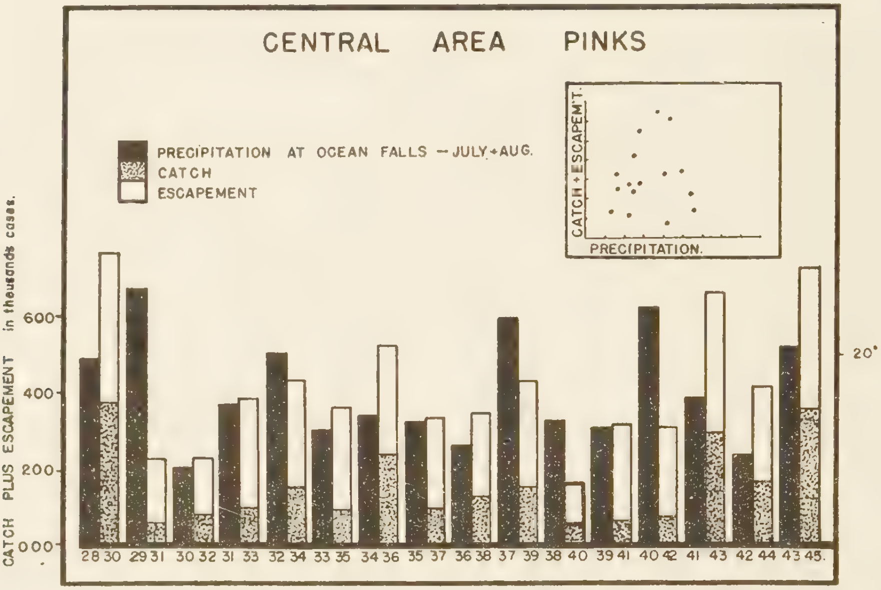

FIG. 3.—Correlation is shown between July-August precipitation at Ocean Falls and the numbers of returning fish at the end of the two-year life cycle. The correlation is improved by taking into account the number of spawning fish (Figure 4).

Field observations indicate that the main losses in pinks and chums occur in the early egg stages. In cohos, which tend to deposit their eggs under less unstable conditions, early losses are usually lower but heavy and variable mortality attends the lengthy free-swimming period spent in fresh water. The graphs support this conclusion as to interspecific differences, while indicating that in both cases stream flow is an important factor in determining the size of the adult population.

With respect to the pink salmon, the views of the present authors have been expressed by Davidson and Hutchinson (1943): "In view of the results from the study of the reproduction of pink salmon at Little Port Walter, Alaska, it is believed that the survival in the streams forms the controlling or critical factor in their reproductive cycle and that the weather plays an important role in this phase of their life cycle".

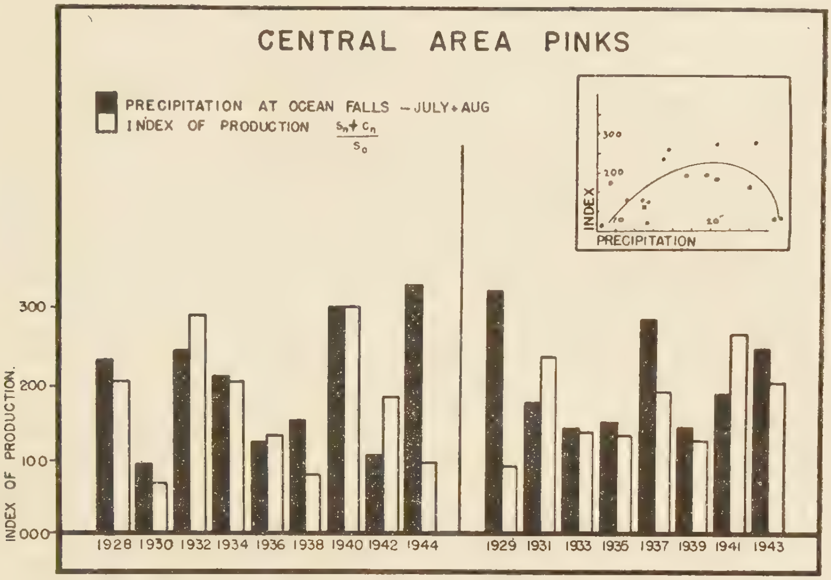

FIG. 4.—Correlation is shown between July-August precipitation at Ocean Falls and the numbers of returning fish at the end of the two-year life cycle. The correlation is improved by taking into account the number of spawning fish (Figure 4).

The general ecological picture of the freshwater phases of the life-history of Pacific salmon, is of a large population injected into a restricted and changeable environment. This environment always causes the major part of the mortality occurring throughout the life-cycle. A specific factor can sometimes be shown to cause serious losses but the elimination of such a factor might result in greater pressure from other quarters. Hence, the measurement of a single factor such as predation or silting cannot be expected to provide an accurate guide to production of adult salmon. It is stressed, however, that changes in volume of water are among the most important features of freshwater life and that various more immediate causes of death or survival can be linked with such changes.

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THE OBJECTS OF FRESH-WATER FISHERIES RESEARCH

By K. RADWAY ALLEN, Fisheries Laboratory, Marine Department, Wellington

FISHERIES research is an applied branch of science, having as its object the obtaining of the knowledge needed for the handling of our fisheries resources so that the maximum sustained yield can be drawn from them. Like most applied sciences, it grades at one end into the fundamental research essential to provide a background, and at the other into the application of existing knowledge and techniques to the solution of local problems. Fundamental research in this connection is concerned mainly with the biology of fish and the organic and inorganic features of their environment, and is largely carried out in the universities and other research schools. The application of knowledge to technical services, such as the diagnosis of disease, may be and should become still more the province of fisheries maintenance workers and administrators. Fisheries research in the strict sense lies between these two extremes, and is largely undertaken by specialized organizations set up for the purpose.

Some of these deal with specific problems, either of fish biology or concerning particular fisheries, but most fisheries research is carried out by organizations with much wider terms of reference. These are generally governmental bodies, often attached to the departments administering fisheries, and are usually responsible for conducting research with the object of assisting the maintenance or improvement of the fisheries in the area in which they operate. Such bodies frequently have to deal with a number of different fisheries, which may differ widely in their nature. In these circumstances the practical value of the results obtained must depend largely on the research policy followed, particularly on the selection of research problems and the degree of concentration of effort.

Although man has exploited fresh-water fish for food or for sport from time immemorial, organized research for the benefit of these fisheries has been of very recent development. It was the decade following the First World War that saw the first establishment of fresh-water research organizations in many countries. Canada, England and New Zealand are among the countries which either commenced or greatly expanded their fresh-water fisheries research organizations during this time. Although a valuable foundation, particularly of the taxonomy and general biology of fish, had been built up by earlier workers, largely in the universities, it was natural that the biologists entering this new field in the middle 1920s should be attracted by problems of a different type from those being studied today, and since that time there have been several well-marked changes in the fields attracting most attention.

In order to study these trends more precisely, an analysis has been made of the subjects of papers on fresh-water research topics published in the Transactions of the American Fisheries Society between 1926 and 1945. Prior to this time the proportion of papers in this journal which dealt with definite research results, as distinct from expressions of opinion and the recording of general experiences, was relatively small, and the journal can hardly be regarded as a research publication in the modern sense. Although this journal is largely restricted to the recording of North American work, it appeared most suitable for the present purpose, both because it is the largest journal specializing in fresh-water fisheries research, and because the area from which its papers are drawn seems to be the scene of more active research in this field than any other region, and has probably considerable influence on developments in other parts of the world. It is noticeable, however, that there is a tendency for each country to specialize in research along particular lines, or upon particular groups of problems, although it appears that to some extent at least the underlying outlook has undergone similar changes in many countries.

In the analysis the papers were classified under a few main heads. The percentage of papers in each five-year period which appeared to fall into each type are shown in the following table:

	1926-30	1931-35	1936-40	1941-45
Improvement of methods . .	54·3	36·3	28·3	19·6
Effect of human activities . .	8·7	4·2	1·4	0·9
General biology	18·5	30·9	35·8	24·8
Critical studies	2·2	1·8	6·8	16·3
Local problems and surveys . .	5·4	7·7	6·1	10·3
Quantitative studies . .	0	6·5	11·5	12·8
	89·1	87·4	89·9	84·7

The remaining papers, approximately 10 per cent in each case, deal with many different subjects, none of which is represented by a significant number. It is immediately evident that in recent years the research effort is being distributed much more evenly than was the case earlier, and it is also clear that a more critical outlook has been developed. This is shown particularly by the progressive decrease in the amount of work devoted to the "improvement of methods", and the corresponding increase in "quantitative and critical studies". Most of the work included under the heading "improvement of methods" has been devoted to increasing the number of fish which can be produced in hatcheries and liberated in the fishing waters. This includes nutritional studies for the purpose of finding more efficient and cheaper foods for hatchery use, the study of the cause and control of disease, and the development of improved forms of hatchery equipment and methods of transportation. In later years an increasing, although still relatively small, proportion of the work included under this heading has dealt with means by which habitats may be improved, generally by the erection of artificial structures. All these studies have, however, been devoted to the improvement of existing practices, without questioning whether these are in fact yielding results commensurate with the effort involved.

The research listed as "critical studies" had as its object the evaluation of management practices in terms of the actual results which they achieve in improving the yield of the fisheries concerned. A great deal of such work has been devoted to the comparison from one aspect or another of the yield to fishermen of a given quantity of eggs when spawned naturally, or when reared to various stages in hatcheries. The comparison of the effect of various differences in stocking procedure, such as changes in age and season of liberation, and in methods of distribution, has also been included. In recent years some critical studies have also been undertaken on the real value of other management practices, such as habitat improvement. The very striking increase, by nearly eight times, in the proportion of this type of research reflects an increasingly critical outlook on the part of fisheries biologists, and less willingness to accept the view that existing practices are fundamentally sound, and only require improvement in detail.

These critical studies had necessarily to be quantitative, since they involved the comparison of different procedures. It seems very likely that this critical approach led to the appreciation of the value of quantitative data on all aspects of fisheries biology, and we find that other quantitative studies underwent a similar increase. The main fields of quantitative work have been the measurement of the size and composition of wild populations, and the study of fishing intensity and yield. Comparison of the amount of combined critical and other quantitative work with the amount of research on improvement of methods emphasizes very strikingly the change which has taken place; in the first five-year period, the combined total of papers on the former subjects forms only 4 per cent of those on the latter, but in the last period it has risen to 148 per cent. An interesting comment representing the point of view during this period of transition was made by Wickliff in 1934 at the conclusion of a comprehensive survey of the fishery research then being carried on in North America; he wrote: "The environment is now considered a major factor for successful fish planting and in the future habitat control or improvement seems to be a necessity, or the many thousands of fish planted will not give the sportsmen full value for their fishing license money." It seems that while it was realized at this time that bigger and better plantings were not the sole means by which fisheries could be improved, it was also felt that they formed the essential basis of a fishery, and that the main problem was to ensure that the liberated fish found a satisfactory environment. It was only gradually, as the early critical studies came to fruition, that it was realized that in many instances the wild fish could, by natural reproduction, fully maintain themselves where the habitat was suitable.

This early interest in habitat improvement is reflected in the original high level and subsequent decrease in the number of papers on "effect of human activities". These deal with the effects on fisheries of various activities of mankind. Although unintentional and often indirect, these effects may sometimes be significant. The most important of these are pollution and the effects of dams and impounded waters. While pollution is still recognized universally as a serious practical problem, it appears now to have advanced beyond the research stage on the fisheries side in most countries, and while much research on the biochemical, chemical and engineering problems is still carried on, fisheries activity seems to be usually concentrated on the administrative aspect of the problem.

At all times a more or less constant proportion of investigations has been concentrated on the study of the condition of particular fish stocks or fisheries, although even among these there has been a tendency for the methods of approach and techniques used to change in accordance with the general alteration in outlook.

The other major field work is that dealing with the various aspects of the biology of fish. Activity in this field showed an early increase and for a time it became the most frequent subject of research. Later, however, it was overshadowed by the critical and quantitative studies. Within this field certain trends of concentration on particular phases were also noticed. A considerable proportion of these papers have always dealt with feeding habits. Spawning habits and the associated migrations attracted much attention in the early biological studies, but once the main essentials were known interest in these decreased, and in recent years much more interest has been shown in the growth of various species of fish in different habitats. This late development of growth studies in North America is in striking contrast with events in Europe, where there was an early interest in this work. This probably resulted from the discovery at the beginning of this century, of the possibilities of scale reading, and its applicability to that very valuable fish, the salmon. This interest in growth phenomena has continued and has completely dominated European research on the salmon, almost to the present day, although there has lately been a noticeable extension on to studies of its migration in the sea. There is a temptation to think that the discovery that fairly reliable data regarding the previous history of a fish could be obtained by examination of its scales has in some cases been an ultimate disadvantage to the cause of fisheries research. The fact that it was technically simple to produce results of biological interest in this way seems to have led to a concentration on this type of work, which has resulted in the filling in of a great amount of detail regarding those aspects of the biology of the salmon which can be studied in this way, but has led to the neglect of other equally important aspects which cannot be studied by quite such simple techniques. In a method as essentially subjective as this it is quite possible for a worker to produce results which are to him reproducible, but which may contain systematic errors of sufficient extent to imperil seriously some of the conclusions. There appears to be a remarkable absence of critical studies devoted to this aspect of the problem.

Summarizing this analysis of one section of published research work on fresh-water fisheries during the last 25 years, we see that there was at first a decided tendency to assume that existing management practices were sound, and that all that was required of the research worker was to find improved methods of carrying out the same procedures. Gradually, however, it was realized that more fundamental research was necesary, and that more knowledge of the general biology and way of life of the fish concerned was essential to the development of efficient means of improving and maintaining fisheries. As this knowledge was accumulated a more critical outlook on existing practices was developed, and more and more work was undertaken to investigate the soundness of these practices, and the quantitative relationship existing in exploited fish stocks.

The delays in publication caused by the recent war, and the fact that work being published at any time has generally been planned and carried out over several preceding years, cause this analysis to terminate with work which was being actually planned almost five years ago. Despite this, there seem to be some definite lessons which may be learnt from the study of past developments, and of the trends shown in the analysis.

While the above summary is written as though all workers and institutions have at the same time the same outlook and approach to the general problem, it is obvious that this is not, in fact, the case. In any branch of science fundamentally new ideas and concepts are comparatively rare, and much research will always consist of filling in the details in the part of the picture which each major advance reveals, and in applying the new technique as widely as possible. While the checking of new and interesting results is always desirable, this is a process which can be carried too far. In a science like fisheries research, which is inevitably organized on a regional basis, the question is always arising: "Does so-and-so apply to our waters, or our fish?" I would suggest that the scientist responsible for planning research programmes should always approach this question warily. However necessary it may be to know the answer, this may often be found without repeating in great detail and elaboration the original investiations in a new locality. A survey of the literature leads to the belief that the repetition in a new locality of work previously done elsewhere has often been carried to the point where a waste of valuable research effort is involved. While this situation arises in part from a well-meaning desire to ascertain the local position, I cannot but feel that it is also due in part to the fact that it is easier to re-apply techniques already known than to develop new ones.

The other major lesson which I believe may be learnt from a survey of past research is a more positive one. That is the necessity for a clear appreciation of the problems which, when answered, are likely to make a real addition to our knowledge of the means whereby our fisheries may be benefited. It is obvious that a general knowledge of the biology and habits of the species is essential as a basis, but once this has been obtained the more detailed investigations which may show the way to valuable methods of management become possible. The questions which seem most likely to yield valuable results generally belong in some form or other to the type: "Is such-and-such a factor having a significant effect, either beneficial or harmful, on the fishery, and, if it is, can we do anything effectively and on an economic basis to augment or reduce its effects?" The careful selection of problems of this type, together with a preparedness to develop new techniques if these are required, will probably do much to ensure that the available research resources are used as effectively as possible.

In the preceding paragraphs much emphasis has been placed on the need for careful selection of problems if fisheries research, as an applied science, is to achieve its objects—the ultimate production of the optimum yield from our fishery resources. This does not imply the necessity for any excessive degree of planning imposed forcibly upon the research worker, for whether the decision as to the problems to be investigated is made by a committee, by the director of a research team, or by the individual scientists, the decision has still to be made, and there is ample scope in the wide field of fresh-water fisheries for the selection of problems which will offer possibilities of making ultimately a real contribution to the benefit of the fisheries, while having regard for local conditions and facilities, and the special abilities and inclinations of the scientist concerned. The one thing which does appear essential, and one which unfortunately is not always achieved in practice, is that the selection should be made by scientists capable of appreciating the fundamental principles involved, and not, as sometimes happens, by administrators who lack the scientific training necessary for this purpose.

In conclusion, every fisheries scientist will have his own ideas as to what are the most significant problems in the sphere in which he works, but I should like to mention two matters which appear to me to be of great importance, and which offer scope for development along new lines, and by new techniques. One of these is the problem of mortalities under natural conditions; considerable progress has been made in recent years in the study of mortality from year to year in fish populations, but there appears to be great need for more detailed work on this question. This applies particularly to the distribution of mortality within each year, and especially within the first year of life. Present evidence suggests that in many cases great mortality may occur during the first few months, or even weeks, after hatching, but there is opportunity for the development of new techniques which will permit of close analysis of this, and also of the causes to which the deaths are mainly due. Studies of these causes might reveal new and valuable means of increasing fish populations.

The other field which I want to mention is that concerned with the ultimate productivity of fresh waters. Study of the quantitative relationships between inorganic nutrients, plants, invertebrates, fish and the yield to man: in other words, of the whole involved food-cycle: should ultimately make it possible to determine the maximum yield which could be hoped for from a given water, and thus provide a valuable means of assessing the effectiveness in increased yield which is obtainable by measures designed to increase the stock numerically, as, for example, the reduction of predators. In the absence of this knowledge, we are frequently facing the possibility that effective measures to increase a stock numerically may only result in a decrease in the size or growth rate of the individual, and so in no gain, or possibly even in a loss, in the yield to man. At the present time it is noticeable that these problems are being approached from different directions by two groups of scientists—the limnologists, who generally view the chain from its beginning in the inorganic salts, or even the solar energy absorbed, and the fisheries biologists, who are working backwards from the fish populations and crops. In the last few years these groups have just begun to overlap in the ground they cover, and it is becoming apparent that they have developed distinctly different concepts, and, unfortunately, different terminologies, and that, with a few notable exceptions, each group is largely unaware of the work of the other.

In a recent paper Macfadyen has made a valuable attempt to create a synonymy of the terms in use, and has also pointed out that confusion has arisen in part through the fact that some workers are dealing with an energy cycle, while others are concerned with the circulation of matter. The fundamental difference between these cycles is that there is a recirculation of matter within the system since the medium acts as a reservoir of nutrient salts, but that the energy is passed progressively from stage to stage until it leaves the system in the form of heat. As the measurement of the energy intake is a relatively simple matter, this permits the estimation of the basic productive activity of the system. Since, however, the energy intake is a function of the density of phytoplankton and other vegetation, except where this is exceedingly dense, it is not a fundamentally fixed quantity, but depends upon the supply of nutrients, or even of one limiting nutrient. This in turn depends both on the supply from outside the system and the amount recirculated from higher trophic levels.

In fisheries research the primary concern is, however, with the highest levels of the chain, and here the quantities which have been regularly measured with existing techniques are the number and mass of the population at a particular instant, and the amounts drawn off by man. It is also possible to measure the total annual production at this level although this has been rarely attempted. Isolated measurements of these quantities are, however, of little value in attempting to forecast the effect of management practices, and such forecasts are the main object of this phase of fisheries research. When considered from the viewpoint of productivity, a fish population may lie anywhere between two extreme types. In one type the total productivity is constant, and any numerical change will bring about a compensating change in growth; at the other extreme are populations in which growth rate is independent of number. Both of these types are readily susceptible to mathematical treatment which enables the desired forecasts to be made. Since, however, the two extremes are entirely different in their behaviour, and actual populations may lie at any point between them, it is essential to know the characteristics of a population in this respect before its response to modifications can be forecast and the conditions for maximum yield determined. Chamberlain has determined the latter empirically for a number of trout streams, but there have been surprisingly few attempts to study the effects of modifications of population density even as far as the effect on growth rate is concerned. I believe that work of this type on various fish populations would at least give a general knowledge of which of the population types mentioned earlier actually occurs, and in conjunction with an attempt to correlate the results with the basic productivity as shown by limnological data would do much to assist us in developing means of obtaining the maximum yield from our fisheries.

FACTORS AFFECTING THE SIZE AND GROWTH OF YOUNG SALMONIDAE IN NEW ZEALAND

By Derisley F. Hobbs, Fisheries Laboratory, Marine Department, Wellington

Introduction

There is a paucity of published information on causes of differences in the rates of growth of individual trout occupying the same environment. There has been speculation as to whether a capacity for more rapid growth can be inherited. Attempts have been made in North America to select rapidly growing strains of trout for purposes of pisciculture. Work done in Norway on brown trout (*S. trutta*) over 30 years ago by Dahl (1918) threw light on this question, but Dahl's work has often been overlooked by subsequent workers.

Dahl showed that, irrespective of whether eggs were collected from fish of fast-growing or slow-growing stocks, the size of eggs greatly influenced the initial size of young and their capacity for growth during the first year of life. Initial disparities in size, as eggs, increased strikingly when young fish were reared experimentally under equal conditions with a stated excess of food present. For example, there were produced from batches of ova of mean weights of 144 mgr. and 176 mgr. fish which as yearlings weighed 1,061 mgr. and 2,944 mgr. respectively.

Dahl found, further, from scale reading, as many other workers have since observed, that differences in size of trout as yearlings tended to be maintained throughout life.

These findings led Dahl to suggest a theory as to the mechanics of stock degeneracy. This was that as a stock increased beyond certain limits the food supply would prove inadequate for maintenance of the earlier growth rate; therefore size of trout would fall; therefore smaller eggs would be produced and the progeny would have a lower inherent capacity for growth.

THE PROBLEM

Did Dahl's work indicate rules of general application and significance? The major facts recorded by Dahl are not questioned—namely that under equal circumstances size of eggs greatly conditions size of progeny during the first year of life and that usually in any environment those trout which have grown best during the first year tend to maintain their early advantage in size. What is not so clear is whether, in natural waters, size of eggs is usually a factor of paramount importance in determining the size to be attained by young trout in the first year of life.

As a study, secondary to work on the natural reproduction of trout reported on elsewhere (Hobbs, 1937), the writer made, in 1934, preliminary observations on the nature of factors influencing the early growth of brown trout in certain New Zealand waters. Although considered too inconclusive to warrant detailed publication, some results of these observations are now briefly summarized in the hope of provoking interest in aspects of the biology of trout which have tended to be neglected.

AREA STUDIED AND NATURE OF OBSERVATIONS

Observations were made at Inchbonnie in tributaries of Lakes Brunner and Poerua. The former drains, via the Arnold River, into the Grey River on the west coast of the South Island of New Zealand. Lake Poerua drains into the Crooked River and then into Lake Brunner. Both lakes contain brown trout. The Lake Poerua fish are larger, better-conditioned and somewhat faster growing than those in Lake Brunner. Interchange of stock between the two lakes is physically possible but is not known to occur. School Creek, draining into Lake Poerua, is essentially a nursery stream containing almost exclusively immature fish, except in winter, when larger fish enter from the lake to spawn. Pigeon Creek and other tributaries of the Orangipuku River, which drains into Lake Brunner, serve mainly as nursery areas for the progeny of spawners which enter from that lake. No significant difference was apparent, from direct observations or from the reading of scales, in the size or quality of mature fish in winter in different tributaries of the Orangipuku River. These streams are shown in Fig. 1; and some further description of them appears in an earlier paper (Hobbs, 1937).

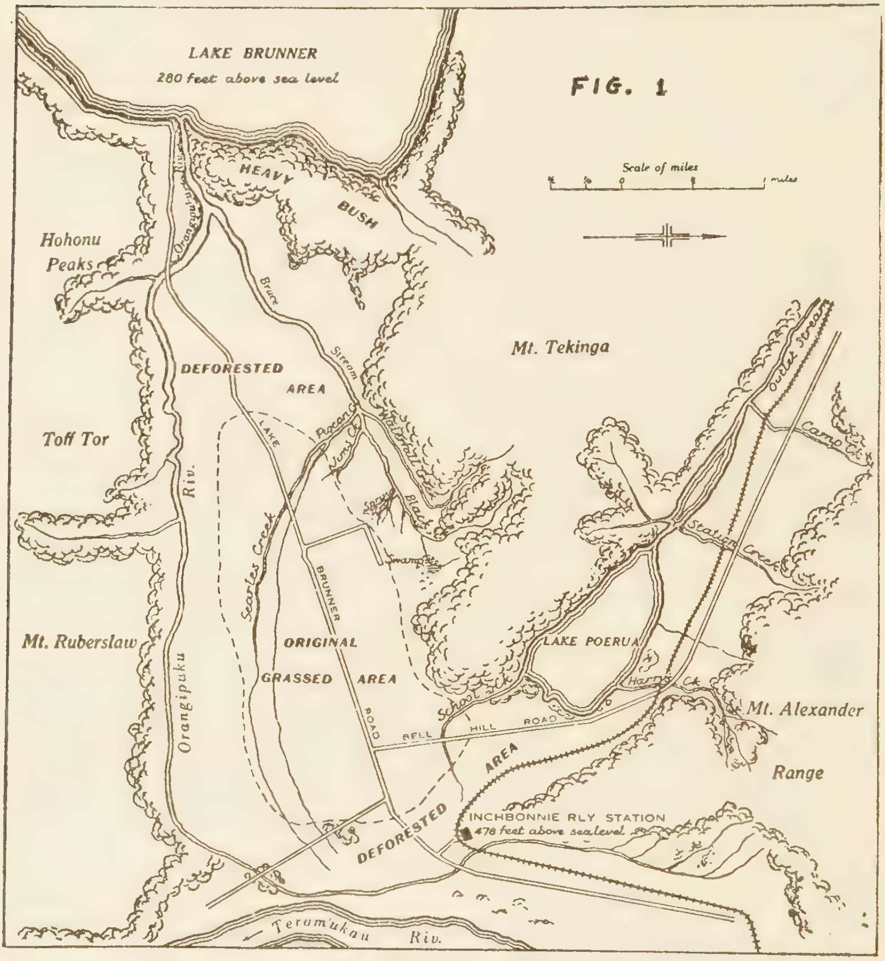
FIG. 1
LAKE BRUNNER
280 feet above sea level
Scale of miles
miles
HEAVY BUSH
Hohonu Peaks
Orangipuku Riv.
Bruce Stream
Mt. Tekinga
DEFORESTED AREA
Toff Tor
Riv.
LAKE
Pigeon Cr.
Waterfall Cr.
Black
Swamp
Searles Creek
BRUNNER ROAD
ORIGINAL GRASSED AREA
Mt. Ruberslaw
Orangipuku
Outlet Stream
Camp Cr.
Station Creek
LAKE POERUA
Harris Cr.
Mt. Alexander
Range
School Cr.
BELL HILL ROAD
DEFORESTED AREA
INCHBONNIE RLY STATION
478 feet above sealevel
Teramukau Riv.

Traps were maintained, with insignificant breaks, throughout the spawning season in School Creek and in Pigeon Creek. Sex, weight and length of fish were recorded. Scale samples were taken and subsequently they were read for the writer by Mr. Arthur Parrott. The size and numbers of eggs produced by individual fish were studied.

Observations were made on the duration of the spawning season in the streams trapped and in additional tributaries of the Orangipuku River. Temperatures were recorded. Samples of young fish were later collected at intervals during the first year from tributaries of the Orangipuku.

GROWTH OF TROUT

Scale reading showed rather better growth of mature fish taken from School Creek than of those taken from Pigeon Creek. Calculated lengths of fish in cm. at successive ages in the two waters are as follows:—

	1st Yr.	2nd Yr.	3rd Yr.	4th Yr.	5th Yr.	6th Yr.
School Creek	9·2	20·3	31·7	40·4	46·2	52·3
Pigeon Creek	8·9	19·0	29·8	36·8	43·6	44·1

Two hundred and twelve four-year-old fish from the Orangipuku system were separated into groups, according as their calculated length as yearlings had been below 8 cm., 8-11 cm., or over 11 cm. Lengths of the groups in subsequent years were as follows:—

Group	1st Yr.	2nd Yr.	3rd Yr.	4th Yr.
Under 8 cm.	7·6	16·9	27·4	36·5
8 - 11 cm.	8·9	20·1	30·3	38·3
Over 11 cm.	10·5	24·3	34·5	40·0

These data suggest that here also, as Dahl had shown in Norway, the effects of factors which determine size as yearlings have a marked influence on size at subsequent ages.

DURATION OF SPAWNING SEASON

Fish entered traps in a condition ready for immediate or very early oviposition. Observations in different tributaries showed that spawning usually took place shortly after spawners entered. Commonly females spawned within 72 hours and sometimes within 24 hours of entry. They returned downstream while the tributaries were still swollen with rain water or at the first subsequent rise in water level. Males, which at all times were greatly less numerous than females among fresh entrants, commonly remained longer upstream and mated with successive females. Thus, while trapping figures show an overwhelming preponderance of females, observations and netting often showed more males than females in the spawning areas.

The run was of shorter duration in School Creek than in Pigeon Creek—92 days from first to last entry as against 133 days. Observations did not cover all tributaries of the Orangipuku River, but 160 days elapsed from the time the first fish was observed working on a redd until the last was observed.

In both School Creek and Pigeon Creek, the ratio of males to females entering remained fairly constant at all times. The over-all ratios from the season were 1 male : 2·74 females in School Creek and 1 male : 2·41 females in Pigeon Creek. Data relating to males have been weighted accordingly for presentation in Fig. 2.

There was a tendency for age and size of females to fall slightly as the spawning season progressed. In Pigeon Creek the mean ages and lengths and also the numbers of females trapped in four successive monthly periods, commencing 22/5/34 - 21/6/34 were, respectively, as follows:—

Age in years	4·24	4·20	4·01	3·90
Length in cm.	40	39	37	36
No. of females	20	80	72	10

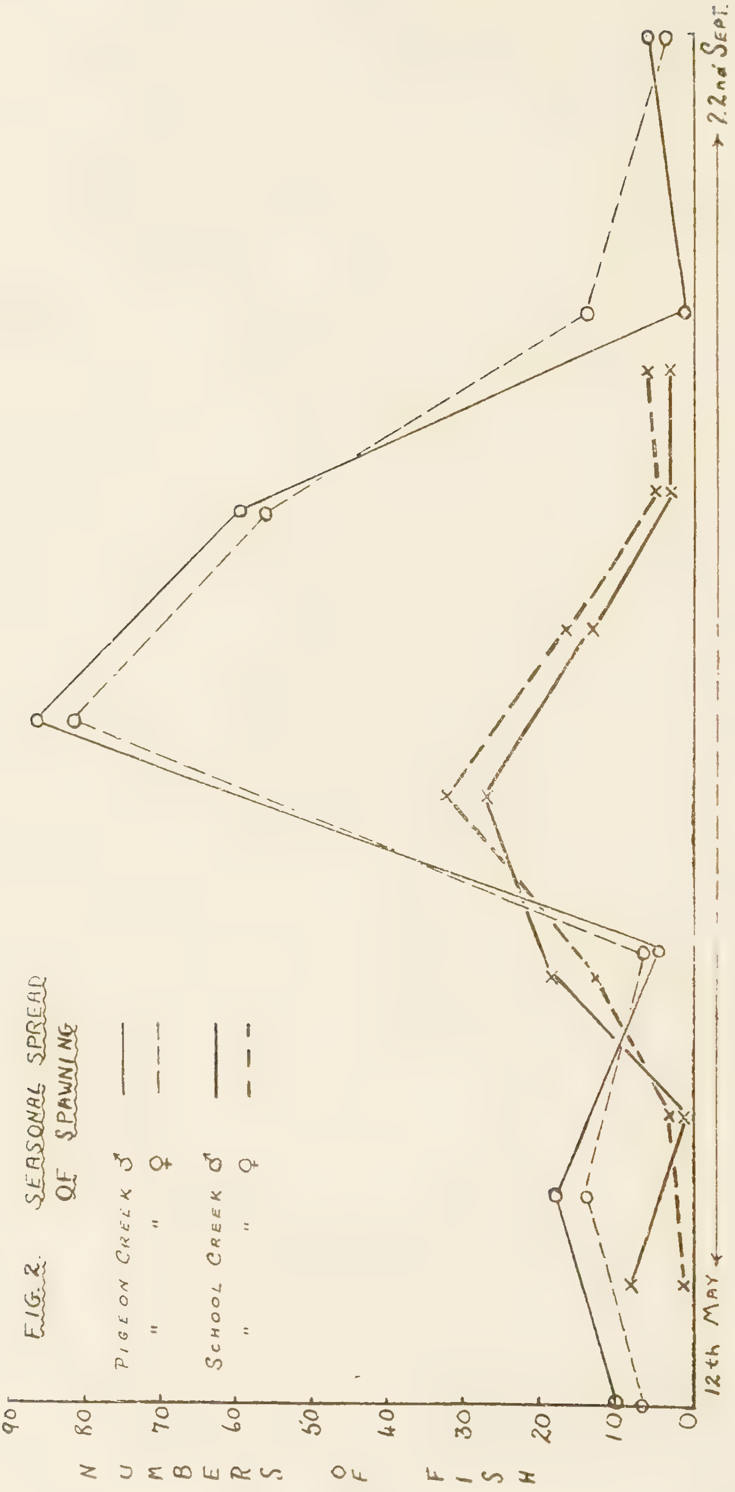

FIG. 2. SEASONAL SPREAD OF SPAWNING

It is clear that there is no tendency for smaller fish, which usually produce smaller eggs, to spawn earlier and thereby to offset any disadvantages pertaining to smaller eggs.

SIZE OF EGGS

Samples of eggs were obtained from 186 females which entered Pigeon Creek and 72 in School Creek.

The greatest observed difference in mean weight of eggs of individual females from either water was about 2·3 times.

Eggs of the smallest mean weight — namely 54 mgr. — were obtained from a stream fish of 27 cm. in School Creek. The largest eggs, of 125 mgs., were from a lake-run fish of 44 cm. in Pigeon Creek. Numbers of females considerably longer than 44 cm. were taken in both waters, the maximum being one of 59 cm. from School Creek.

Usually eggs of any individual fish tended to be very uniform in size. Exceptionally among eggs of fairly uniform size a few extremely large or small ones would be found. Thus although, in mean size, the products of different fish varied by less than 2½ times, variation between individual eggs was as much as eleven times — 17 mgr. as against 190 mgr.

The screening of approximately 2,000 gm. of eggs from fish of various sizes in Pigeon Creek showed 26 per cent above 110 mgr., 73 per cent from 80 to 110 mgr., and 1 per cent from 50 to 80 mgr. Eggs above 140 mgr. or below 50 mgr. were in each case less than 0·2 per cent of the total.

In either stock the larger fish tended to produce larger eggs. Age alone did not appear to influence size of eggs when comparison was made of eggs of three- and four-year-old fish and again of four- and five-year-old fish of like lengths.

As between four-year-old fish in the two streams, the following significant differences in size of eggs relative to length of parent were found. Length is given in successive 3 cm. groups. Weights of eggs are in mgr.:—

Length in cm.

	31-4	34-7	37-40	40-3	43-6	46-9
Pigeon Creek	71	81	90	96	95	—
School Creek	70	72	73	75	78	85

Causes of these differences are obscure. At any given length the School Creek fish were usually heavier. On the Corbett scale, the School Creek fish had a mean condition factor of 55 against 46 in Pigeon Creek. As between the two stocks, the better conditioned fish of School Creek produced greater numbers of eggs but eggs of a smaller size. It is not clear, however, that this is so between otherwise similar individuals of either one stock.

Variation is evident in the size of eggs of fish of the same age, length and weight. Fig. 3 relates to means of pairs of fish among the Pigeon Creek four-year-olds which, at the particular lengths, had identical weights. It suggests that size of eggs may vary inversely to condition of parent. However, without more material this cannot be regarded as well-founded.

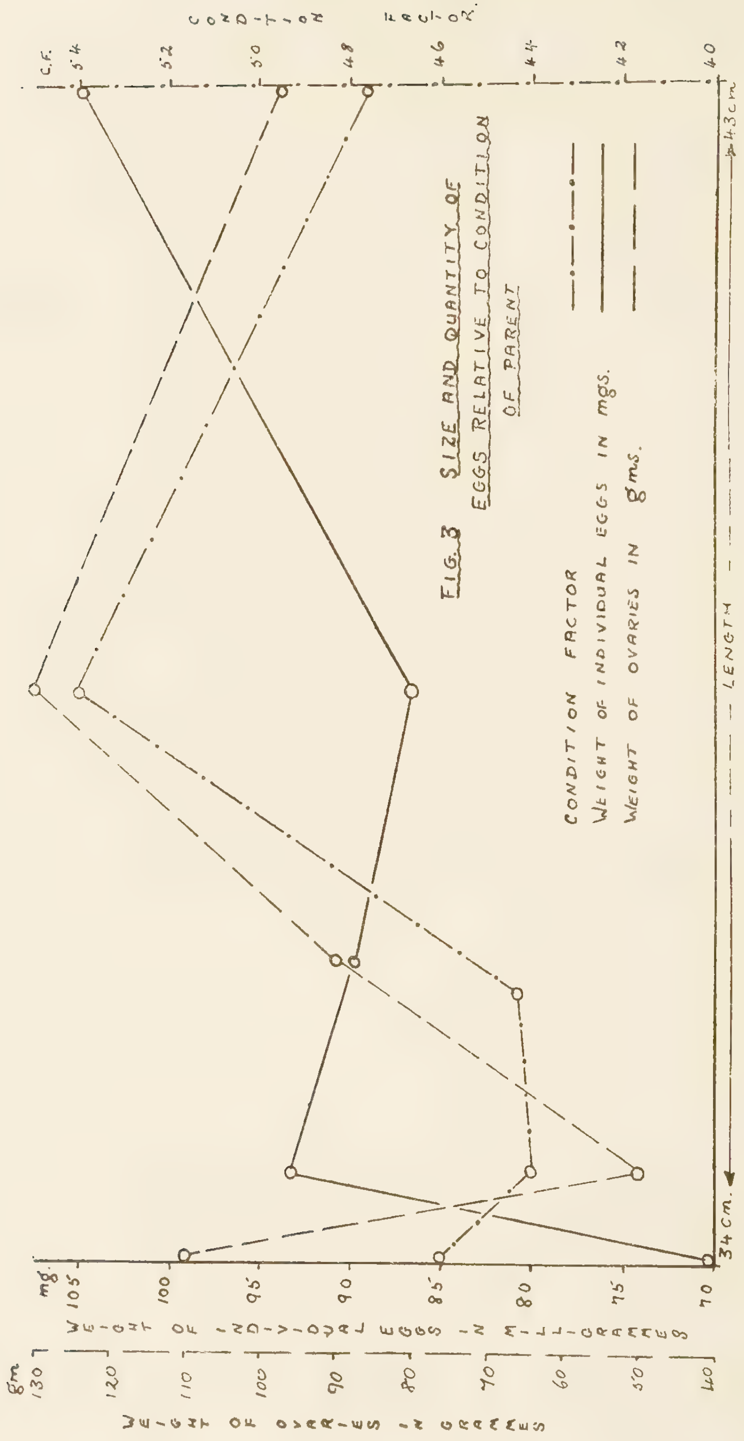

FIG. 3 SIZE AND QUANTITY OF EGGS RELATIVE TO CONDITION OF PARENT

Incubation and Larval Development

It has been shown that eggs are produced over a very long period. There are considerable differences in size of eggs produced at any time within that period. There is a slight tendency for larger fish, producing larger eggs, to spawn earlier. The tendency is too slight to result in any strikingly progressive decline in size of eggs produced as the spawning season advances.

Hereafter attention is limited to portions of the Orangipuku River system which serve as spawning ground for stock entering from Lake Brunner. Is size of eggs the only factor or even an outstanding factor in bringing about differences in size as yearlings—differences which seem to condition greatly the subsequent growth of these trout in Lake Brunner?

It has been shown that spawning in these tributaries extends for at least 160 days. If temperature in all tributaries remained constant and was the same in all tributaries, then differences in times of deposition of eggs would be followed by parallel differences in times of emergence of fry. The temperatures which control the rate of the development of ova and larval fish in certain of these tributaries are shown in Fig. 4. Incubation proceeds slowly at low temperatures and more rapidly at high temperatures. Within limits, Seth Green's rule applies to brown trout and at 50° F. hatching occurs in 50 days. It is advanced or retarded by five days for every degree higher or lower respectively. Larval development is completed in about 50 days at 50° F., although fry emerge and commence feeding earlier while a proportion of internal yolk remains to be absorbed. The rate of larval development is similarly influenced by differences of temperature.

It is an over-simplification to consider only this effect of temperature. The Cambridge workers Gray (1928) and Wood (1932) have shown that the efficiency of conversion of yolk to new tissue is constant only between certain limits of temperature. Maximum efficiency of development takes place between 6·6° C. and 12·2° C. (indicated by stippling in Fig. 4). Outside these limits wastage of yolk occurs which results in the development of smaller fish than the eggs would otherwise have produced.

Of the three tributaries, Jims Creek alone is of a temperature which ensures maximum efficiency of conversion of yolk to new tissue. Further, temperatures in this stream are sufficiently uniform to ensure that initial differences in times of deposition of eggs are, to a substantial degree, maintained, with the result that fry emerge after approximately equal periods in the gravel. Emergence of fry will follow about 80 days after deposition of eggs in this creek.

In the other two streams lower temperatures will result in smaller fish being produced from earlier spawned eggs than from eggs of like size spawned later. Incubation will proceed at very different rates according as particular eggs are spawned early or late. Somewhere about 140 days will elapse (as against 80 in Jims Creek) from the peak of spawning activity in July until resultant fry emerge in Black and Waterfall Creeks. Because in Black and Waterfall Creeks most eggs are subjected to temperatures which are tending to rise, any advantages resulting from earlier deposition of eggs will tend to be reduced.

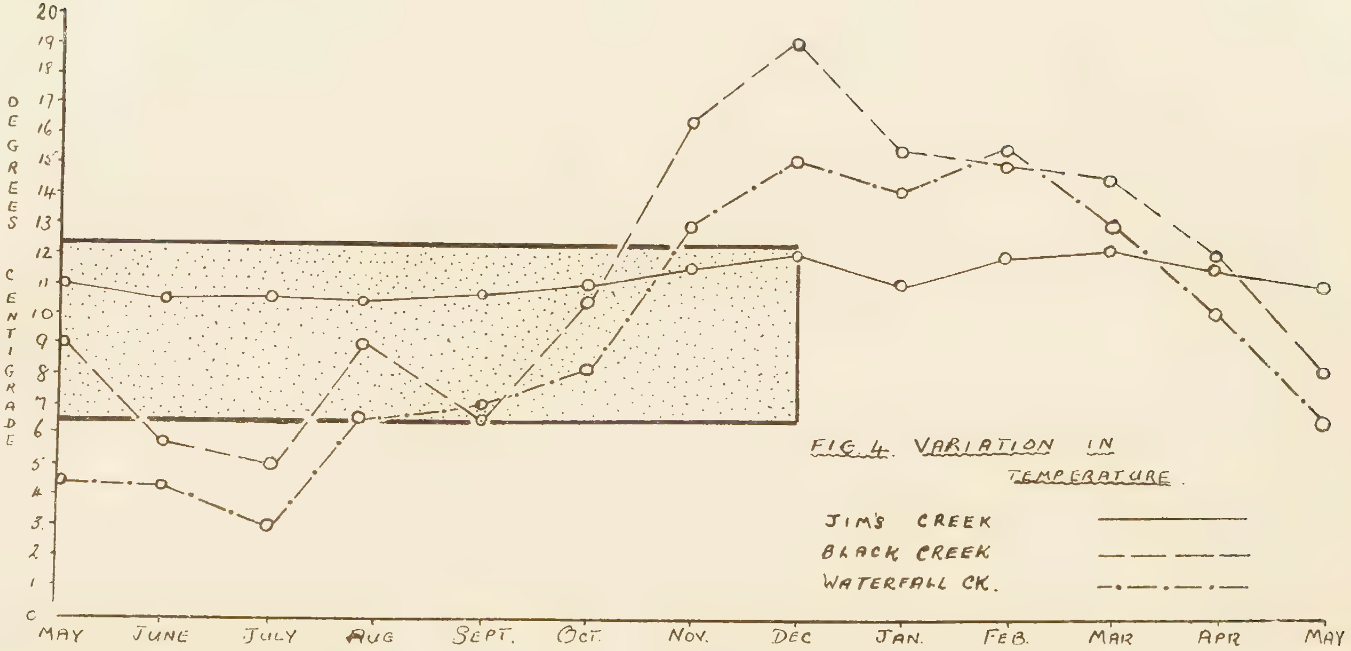
FIG. 4. VARIATION IN TEMPERATURE.

The initial size of trout produced in these different waters is shown to be conditioned by the size of eggs from which they hatch. In certain tributaries the potential initial size is reduced by temperatures unsuited to the most efficient development of embryos and larvae. Where temperature is fairly uniform, fry emerge over a period of similar duration to that over which spawning extends. Elsewhere the relative duration of the hatching period to the period of deposition is modified. It is clear that, even if eggs were uniform in size, fry of different sizes could be expected to emerge at very different times in different parts of what are nursery areas for one stock. In the Inchbonnie streams fry emerge into physically and biotically dissimilar environments. Because of differences in food resources, differences in concentration of fish relative to such resources, and differences in temperature, which could condition both appetite and proportion of food consumed which could build new tissue, unformity of growth could not be expected.

Collections of trout of the year were commenced while additional fish were still emerging and these collections were continued through the summer and in some cases into the winter months. The collecting stations on each stream contained a sufficient admixture of shallow and deeper water to give representative samples. Where available, fords used by cattle were selected as collecting stations. In spring and early summer mean size of fish increased slowly because growth of the older fish was masked by the continued entry of new fish of minimal size. The mean weights of fish collected at successive times are shown in Fig. 5.

The fish in Jims Creek were appreciably heavier at any time than those in Black and Waterfall Creeks which have lower winter and higher summer temperatures. Before March the stock was exhausted at the collecting station in Jims Creek, apparently by migration, because a similar absence of fish then became evident in other sections higher up the same stream.

In Black and Waterfall Creeks, maximum mean weights were recorded in April. Thereafter size fell until early June in Black Creek, when migration appeared complete and further specimens were not obtainable. In Waterfall Creek it is inferred from the continued fall in size that migration of successive fish continued until at least July, when observations ceased.

The observations suggest that in these three waters a usual maximum weight of between about 5-10 gm. is attained before migration occurs. These streams are all of sufficient size to hold greatly larger fish and are indeed, larger, more stable, better provided with cover, and richer in food than streams elsewhere observed by the writer to carry fish of much greater size. Observations did not show conclusively whether fish proceeded directly to Lake Brunner from the different tributaries of the Orangipuku River or whether they delayed for a time further down the Orangipuku. Usually in summer the Bruce branch of the Orangipuku and the latter stream below its junction with the Bruce contain mainly trout of less than one year and a sparse stock of larger mature fish. A single sample of young trout taken in February from the Bruce Stream below the entrance of Black and Jims Creeks showed an average weight of 11·5 gm. This is greatly

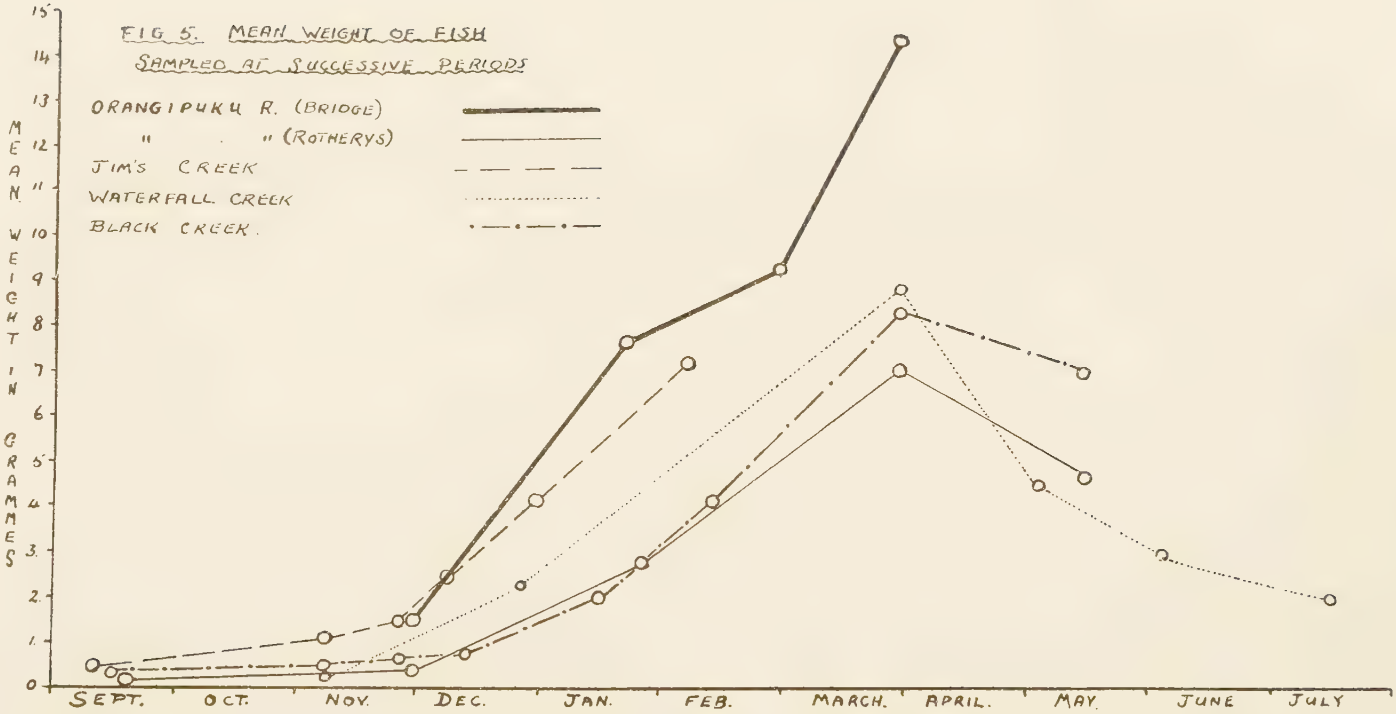

FIG 5. MEAN WEIGHT OF FISH SAMPLED AT SUCCESSIVE PERIODS

above mean weights elsewhere at that time. Whether fish of this greater size were produced where collected and found conditions most favourable there, or whether they were the better grown migrants from tributaries is not known.

Data are included in Fig. 5 from two collecting stations on the Orangipuku River itself. Both were above its junction with the Bruce. The bridge is at the lowest road crossing shown in Fig. 1. Rotherys is at the crossing of the Blind Road higher up and adjacent to the Teramakau River. A few records of temperature in the Orangipuku show less seasonal fluctuation than in Black and Waterfall Creeks, but more variation and lower winter and spring means than in Jims Creek. Fish spawn in large numbers at Rotherys where fry are very abundant in summer. Few fish spawn and fry are less numerous down at the bridge. Here as in the Bruce, it is not clear whether the greater mean weight at the lower station was attributable to lower concentration of fish or other more favourable local conditions, or to migration of larger fish from upstream.

Food and Fauna

It is not proposed to review in detail data on the food of young trout in these waters. Available records had been condensed solely to show in the briefest form that there are significant differences in the faunas at different collecting stations and in food consumed at such stations. Collections at different stations were in all cases made shortly after dusk.

In Table 1 the percentages (by number) are given of different broad groups of food animals in gut contents of trout of between 2 and 9 cm. length. The percentages of such animals in the respective faunas are given in parentheses. Snails (*Potamopyrgus*) and worms (*Eiseniella*) which were abundant only in Jims Creek and which were not consumed by the small trout, have been omitted from the fauna of Jims Creek given in the table.

TABLE I

PERCENTAGE COMPOSITION OF FOOD (AND FAUNA)

Station	*Mayflies*	*Midges*	*Other Aquatic Animals*	*Terrestrial Animals*
Waterfall Creek	26 (16)	43 (49)	24 (35)	7
Black Creek	25 (13)	42 (32)	22 (55)	11
Orangipuku River (Rotherys)	30 (4)	63 (8)	7 (88)	0
Orangipuku River (Bridge)	91 (42)	7 (27)	2 (31)	0
Jims Creek	67 (8)	29 (28)	4 (64)	0

Differences in Sizes of Fish

Differences in mean size of fish at various times in some tributaries are shown in Fig. 5. Disparity in size of individuals was much greater. Weights of individual fish in successive months in the Orangipuku River and tributaries show the following maximum variations both for any one station and as between all specimens irrespective of station:—

Weight of Largest Fish Relative to Smallest

	Any one station	*All stations*
November	24 times	35 times
December	24 times	60 times
January	14 times	30 times
February	6 times	14 times

The samples were small – 11 to 34 specimens with a mean of 19 for all stations within these particular months. Usually samples were taken at intervals of about six weeks. Thus only 13 samples were available from the five stations in the four months. More extensive and ample sampling would undoubtedly have shown greater variation.

Even these small samples show a maximum disparity of 24 times in weight of fry, as against a usual maximum disparity in mean size of eggs of different females of less than 2·5 times. The disparity of 24 times occurred at different stations in November and December, as might be expected following different rates of incubation in the streams. The disparity in size of individuals collected from all stations increased over the period when more material at minimal size was emerging. Thereafter it fell. Greater uniformity is shown later, especially in February, the month when migration exhausted available material in Jims Creek.

The differences, as calculated by scale reading, in length of fish as yearlings in this water-system were such as to suggest a usual disparity in weight up to about 10 times.

CONCLUSIONS

The facts available, although inadequate to show the relative significance of all factors influencing early growth of trout in these waters, warrant the following conclusions.

1. Size of eggs of trout comprising two stocks tended in each case to increase with increase in length of parent. Variation occurs in size of eggs of individuals of one stock even if such individuals are of the same age, length and weight.

2. Individuals of a stock in one part of the water-system produced eggs substantially larger than those of individual fish of like age and lengths comprising a separate stock elsewhere in the same system. The better-conditioned stock produced the smaller eggs.

3. Fish from a common summer feeding ground enter a series of tributaries of the Orangipuku in winter. Spawning extends over a period exceeding five months.

4. Water temperature in various tributaries differs with the result that incubation of eggs is not of like duration nor necessarily of uniform efficiency in different tributaries. Even in the same tributary, incubation of eggs of successive spawners may proceed at different rates and at different efficiencies.

5. A downstream movement of young fish takes place during summer, autumn and early winter and involves, earliest, those individuals of greatest size.

6. The differences in size of young trout during their first summer greatly exceed initial differences in size of eggs. Disparity in size of fish appears attributable to a complex variety of causes which includes the size of eggs, temperature during incubation, time of emergence as fry and the physical and biotic conditions where fry emerge. Combinations of circumstances in these waters appear commonly to bring about early differences in size of trout very much greater than could be attributed to size of eggs alone.

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FRESH-WATER FISHERIES RESEARCH IN NEW ZEALAND

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In a country discovered by Europeans as late in history as was New Zealand, research on fresh-water fish and fisheries cannot have had an early beginning. A few specimens of fresh-water fish were collected by some of the early expeditions, but it has often proved impossible to identify the early descriptions with species known today. It was not until the second half of the nineteenth century, when a definite scientific community was arising in New Zealand, that our present knowledge of the native fish fauna was placed on firm foundations, largely by the work of Hector and Hutton between 1860 and 1880. Since that time, advances have come in a few periods of activity separated by long periods of stagnation, the main progress being due to the work of Phillipps and Stokell. Apart from a few species of economic significance to which I will return later, the position unfortunately still remains that our knowledge of the native fresh-water fishes is largely confined to their systematics, and very approximate distributions. Their breeding and feeding habits, rates of growth and ecological relationships still represent an almost virgin field. This is despite the fact that some of them are both abundant and widely distributed throughout the country.

The native fresh-water fish of New Zealand are small, except for the eels, and have now no value as game fish, while only one of them supports a regular commercial fishery. In these circumstances it was natural that attention should be very early directed to the possibilities of establishing here some of the more desirable species known elsewhere. In all, about 30 species were introduced into New Zealand, generally from Europe and North America, most of the introductions being made between 1865 and 1900. Of these only eleven are known to be still surviving, and three provide excellent fishing in a number of waters. These are brown and rainbow trout, and the king (here generally called quinnat) salmon. Two others, Atlantic salmon and American brook trout, provide good fishing in a few waters, while the remainder are either very localized, or disregarded by anglers, or both.

These five species have been widely liberated, and either brown or rainbow trout, or both, have probably been placed in almost every accessible water in the country. At the present time a high degree of stability seems to have been reached; brown trout are found throughout the country, but are dominant in the South Island and the southern tip of the North Island; rainbow trout dominate the central part of the North Island (there are relatively few trout in the northern extremities), but are found in a few scattered waters in the rest of the country. Quinnat salmon are abundant in the major rivers on the east coast of the South Island and are also established in one river on the west coast. Atlantic salmon are confined to the Waiau River system in Southland, where they seem to be more or less "land-locked", and brook trout occur in a few isolated localities in the South Island.

Little research on the introduced species was done during the time in which they were being established and for a number of years thereafter. A few papers were published recording the progress which had been made in establishing various species, and discussing in some cases factors which seemed to be affecting them. The work of Arthur in Otago is among the most important in this respect. No systematic research was undertaken, and these papers were essentially of a recording and observational nature. They are, however, of considerable historical value for reconstructing the events of the early years of liberation.

Fundamental research in fields allied to fisheries has not been neglected in New Zealand, although it has largely been confined to study of the systematics and biology of various aquatic animals, and to simple physical and biological surveys of the lakes. Of the groups of animals significant in fresh-water fisheries, the most important are the molluscs, Crustacea and insects. The studies over a long period of years of Suter, Chilton and Tillyard respectively have laid a valuable foundation for these three groups, and in more recent years other workers have contributed notably to our knowledge of the systematics and general biology of smaller groups and of particular species. Phillips' studies on the mayflies are outstanding, both for their completeness and because the group is of particular interest to fresh-water fisheries. In general the position with regard to fresh-water invertebrates is rather similar to that concerning the fish: there is a basic, but incomplete, knowledge of their systematics, and some outline of the distribution of the various species, but very little is known of their life-histories and ecology. The biology of a few isolated species has been studied in detail by individual workers, but our knowledge of most invertebrates is in almost all respects more incomplete than it is of the fish. Many of the studies of particular species have been undertaken by students working for M.Sc. degrees. While some of these have been published and so made generally available, most of them have not, and are virtually inaccessible, even if not unknown, to the workers in the same field. There have been improvements in the system during the past year and all theses will in future be filed and be available for reference. It remains, however, that it is still difficult for the interested worker to learn what has been accomplished in his field. In order to avoid this lamentable waste of valuable information it would seem that the publication of at least short abstracts of all theses in a recognized scientific journal is required.

General surveys of fresh waters probably began with the bathymetric survey of a considerable number of lakes by Lucas in 1903, although a few observations on isolated lakes had been made earlier. Later surveys have included biological observations, especially on the plankton of a number of lakes by Percival, and more detailed but localized studies of Lake Taupo by Armstrong. Investigation of the fundamental limnology and seasonal cycles of New Zealand lakes have been rarely attempted, although recently Percival and Parry have studied this aspect of two South Island lakes. This lack probably arises from the absence in New Zealand of any permanent limnological stations situated on or close to suitable lakes. Such stations would make possible the frequency of observations and the elaborate equipment which are necessary for this work. Unfortunately the establishment of limnological stations appears to be remote in a country as small as this, and with such a general absence of institutions for pure research. This is particularly regrettable since the geological youth of the country, and the existence of a chain of glacial lakes in various stages of development, provides exceptional opportunities for studying the evolution of lakes, particularly in the early stages. The natural opportunities seem to be distinctly greater here than in some other countries where limnological research has been able to develop much further.

Like many other countries, New Zealand first began to develop organized research into zoology as applied to fisheries during the third decade of this century. The first native species to receive attention was the inanga (*Galaxias attenuatus*), the young of which are caught in considerable quantities when migrating up the rivers from the sea, and are marketed, both fresh and canned, under the name of "whitebait". It was not until this period that the identity of the adult form and the larval whitebait stage was finally established; this had been strongly suspected by some earlier workers, but had been equally strongly denied by others. In 1929 its spawning habits were finally elucidated, and it was shown that the draining and grazing of the tidal marshes where it breeds must be among the factors which had brought about the reduction in numbers which had undoubtedly occurred. Unfortunately no further advances have since been made, and much remains to be discovered regarding its growth and feeding habits, and the identity or otherwise of the stocks entering the various rivers.

The only other native fish which have attracted attention on economic or practical grounds are the fresh-water eels (*Anguilla dieffenbachii* and *A. australis schmidtii*). These are very abundant in New Zealand and the former grows to an unusually large size, a weight of 20 lbs. being not uncommon, and 45 lbs. being credibly reported. A great many different forms were distinguished by the Maori, but the studies of Schmidt in 1926 showed that in fact only the two species were present. Although these fish formed a very important source of food to the Maori, they have been largely neglected by the white settlers, whose chief interest in them has been as an enemy of the more valuable trout. This aspect formed the main background of studies undertaken by the research staff of the Marine Department about 1937, which did much to elucidate their distribution, feeding habits and growth rate. It was found that *A. dieffenbachii* competed with trout for food to a marked extent when small, and that the large fish (all females) also preyed extensively on trout where these were abundant. The other species is mainly, though not entirely, restricted to waters near the coast, and does not greatly overlap the trout in habitat. Where it does it may affect it as a competitor to some extent, but not as a predator. During the recent war the demand for the utilization of all possible food resources stimulated interest in the eel, which was canned on an extensive scale in a few localities. In association with this, research was undertaken by the Marine Department on the quantity and composition of the migrating eel stocks at Lake Ellesmere, where the concentration of large numbers of migrants in a small area rendered them particularly available for exploitation. Since the war further studies have been undertaken of the magnitude and composition of the eel populations of typical rivers in various parts of the country. The main objects of this work are to determine both the extent of the available resources if further utilization becomes possible, and the effect of the eel population upon the game fish. At the present time no significant utilization of eels is taking place in New Zealand, despite the fact that officers of the Department of Scientific and Industrial Research have shown that they contain a high percentage of oil, and that the flesh is rich in both Vitamin A and D.

Research on the introduced game fish was also started during the 1920s. It was originated by the Acclimatization Societies, which are responsible for the local administration of fresh-water fisheries in most parts of the country; these set up a joint research organization in 1927. This has been continuously in existence since then, although in 1937, when the Societies were unable to continue its finance, it passed under the control of the Marine Department, which was already undertaking research on marine fisheries. Ten per cent of all angling licence fees are, however, still contributed towards the cost of research. Since the recent war this Department has undergone a considerable expansion of staff and facilities. As happened in many other countries, work began in an atmosphere coloured by the belief that large and frequent liberations were essential if the fisheries were to be maintained. Despite this it was realized that it was essential to know more of the biology of trout under natural conditions, and early research was devoted to the age and growth of trout, as shown by their scales, and to their food supplies. An attempt was also made to apply these results to the question of the diminishing return which anglers were obtaining for some waters. The growth studies were carried out on a widespread basis, scale collections being obtained from waters throughout the country, largely by the co-operation of anglers.

In the early 1930s, however, fresh-water fisheries research in New Zealand ventured into entirely new ground. Studies were then commenced with the object of determining quantitatively the fate of salmon and trout eggs spawned under natural conditions, and of testing the correctness of the general belief that natural reproduction was a very inefficient affair. These investigations were carried on in many different parts of New Zealand over a number of years, and the results showed conclusively that except where particularly adverse conditions exist, due to flooding, overcrowding of spawning beds, or unsuitable composition of the beds, natural reproduction is much more efficient than was supposed, and losses are little, if at all, greater than those occurring in the typical hatchery. It is probably not unfair to suggest that this work, following the Cultus Lake studies on the sockeye salmon, has helped materially to promote the present critical approach to the whole problem of hatcheries and liberations. A recently published survey has examined critically the local implications of this problem in New Zealand, as well as of other fisheries management practices now in use or under consideration here.

The realization of the need for further knowledge of the fundamental factors underlying the productivity of trout streams led shortly before the last war to the undertaking of a detailed quantitative study of one particular trout stock. This work, which is now being prepared for publication, was concentrated on the Horokiwi River, a small but typical trout stream near Wellington. Determination of the number of fish at as many points in the life history as possible, combined with studies of the growth rate, has made possible an estimate of the production of trout flesh at each stage in this river. This has been correlated on the one hand with the amount taken by anglers, based on a form of creel census, and on the other with the amount of food available. The latter was estimated by combining the results of regular quantitative measurements of the density of the bottom fauna with a physical survey to measure the actual area of each type of substratum in the river bed. The results have revealed the difficulty of studying relations of this kind without very intensive observations. It has been found that conditions vary so much from section to section, even in such a small stream as this (seven miles long), and, as a result of factors such as floods, from season to season, that results based on a short period of sampling, or on a limited area, have very little significance.

It was found that floods could have a very adverse effect on the production, and since the war more detailed studies have been undertaken on the relation between flooding, shifting of the river-bed gravels, and the density of the bottom fauna. In an extreme case, the disappearance of as much as 97 per cent of the bottom fauna has been observed in a single spate. There appears, however, a possibility that some of the vanished fauna may be buried in the gravel away from the river channel, but may survive and ultimately find its way back to the water. It is hoped to investigate this effect further in the near future.

In the last two years an effort has been made to collect detailed information regarding the size and abundance of trout, and the magnitude of the fishing effort and anglers' catches in rivers throughout the country, by means of the organized collection and analysis of anglers' diaries. The distribution and collection of diaries is being undertaken by the Acclimatization Societies and kindred bodies, and the analysis by the Marine Department. At present the scheme is still in the initial stages and the response is very uneven. In some districts, however, over 10 per cent of the anglers are already co-operating, and the prospects are very hopeful for collection of really comprehensive data in the near future.

As mentioned earlier, the sport fisheries of New Zealand are at present based entirely on a few species of Salmonid fishes. These have already been established in almost all waters to which they are adapted, but there still remain some waters which are not suited to Salmonids, but which might provide a good habitat for some other desirable species. These are principally lakes without significant tributaries, and the sluggish lower reaches of major rivers. They are now receiving consideration, and as a preliminary measure surveys of a number of the lakes concerned are being undertaken, to determine the nature of the environment they offer. When this has been done, it should be possible to select a suitable species of fish for introduction with a far greater chance of success than was achieved by the hit-or-miss methods adopted in most of the earlier introductions.

THE INFLUENCE OF CHEMICAL CONSTITUENTS OF WATER UPON THE MORTALITY OF YOUNG RAINBOW TROUT

By TETUO TOMIYAMA and YOSHIO KOJIMA, Laboratory of Chemistry of Fishery Products, Kyushu University, Japan

IT is known that certain constituents of water influence the growth and mineral composition of aquatic organisms. By treating the water of fish ponds with calcium hydroxide, Walter[1] obtained an increase of 74 per cent in the yield of carp, and Brüning[2] showed by a similar experiment an increase of 31 per cent. Igarashi[3], on adding calcium hydroxide to the water of fish ponds located on a brown coal area in Hokkaido, reported an increase in the precipitable matter, zooplankton as well as calcium by 2-6 mg. per litre, and also increases in the yield of carp, dace, and shrimp amounting to 21 per cent, 28 per cent, and 65 per cent, respectively. These favourable results seemed to be largely due to the indirect effect of adding fertilizer upon the fish.

There have been, on the other hand, several studies which have clearly shown that there is a relation between the concentration of certain inorganic constituents in any water and the amount of these constituents found in aquatic organisms. Hayashi[4] found that the sodium content of adductor muscle of *Mytilus* sp. changed proportionately in brackish water. Usui *et al.*[5] also showed that the calcium content of the pond-smelt caught in lakes Kasumigaura and Karenuma varied proportionately with the amount of calcium in the lake water. Sekine[6] found that trout eggs during hatching absorbed inorganic matter from the surrounding water. McCay[8] also found that the fry of rainbow trout raised exclusively with liver for 90 days absorbed as much as 100 mg. of calcium from the surrounding water, while from liver-feed he took only 30 mg. Kaplanski and Boldirewa[7] clearly showed that, when carp were kept for 30-70 days in water to which sodium or calcium chloride had been added, an increase took place in the concentration of cations in muscle and of anions in blood. The foregoing studies lead to the presumption that certain constituents of natural water if extremely small in amount, or if abundant, will make the mortality higher by disturbing the normal metabolism.

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[1] Walter, 1934. Die Versuche 1931 und 1932 der bayerischen teichwirtschaftlichen Versuchsstation Wielenbach, S. 15.

[2] Brüning, 1932. Allg. Fischereiztg. 279.

[3] Igarashi, 1941. *Rep. Hokkaido Fish. Exp. Sta.* 1.

[4] Hayashi, 1933. *Rep. Inst. Phys. Chem.*, 12: 184.

[5] Usui, Sukegawa, and Shu, 1937. *J. Sci. Fish.*, 5: 315.

[6] Sekine, 1929. *J. Agric. Chem. Soc.*, 5: 601.

[7] Kaplanski, S. und Boldirewa, N., 1933. *Biochem. Z.*, 265: 422.

[8] McCay, C. M. and Tunison, A. V., 1933. *Rept. Cortland Hatchery;* McCay, C. M., Tunison, A. V., Crowell, M., and Paul, M., 1936. *J. Biol. Chem.*, 114: 259.

In carrying out the analysis of a water sample in Oizumi hatchery where a high mortality of young trout had been experienced, the authors noticed that the dissolved matter consisted mainly of silicate. The question arose as to whether or not a correlation existed between the high mortality of trout and the silicate content of water used in the hatchery. Hence, waters of eleven hatcheries in all parts of Japan have been analyzed for various constituents, and the data on the mortality of trout have been collected from eight hatcheries. Interesting results have been obtained by statistical research on the correlation between the two factors under question.

Experimental Methods

In order to avoid as much as possible the change of the susceptible elements, the sample waters were first analyzed for pH, alkalinity, phosphate and oxygen consumed from permanganate, and then for chloride, sulphate, and silicate. When the pH value was not recorded on the spot, it was determined by Tomiyama's simplified double cup method.[9] Total solids was determined by evaporating 100 cc. of the sample water. Tomiyama's micro-volumetric method[10] was used for the determination of alkalinity and oxygen consumed from permanganate, and Tomiyama-Hosokawa's nephelometric method[11] for estimating chloride and sulphate. The determination of phosphate and silicate was carried out by using the ordinary colorimetric method. Calcium and magnesium were determined upon a twenty times concentrated solution of the sample water by the micro-volumetric method and colorimetric method respectively.

Experimental Results and Discussion

1. *The Chemical Composition of Water Used in Hatcheries.*

The analytical data for the waters used by eleven hatcheries are shown in Table 1. Though the data are not complete as alkaline metals were not determined, the analysis for most anions is nearly complete. Hence, the values for milligram equivalent of each anion and each cation have been calculated as given in Table 2. It will be seen from Table 1 that most hatchery waters are spring ones, having a pH value of 6·1-7·5, a total solids value of 60-165 mg. per litre, and a temperature of 9-16° C. Table 2 shows that the bicarbonate ion is always inversely proportional to the silicate ion and that the sum of them so far estimated amounts to 75-94 per cent of the total anions. In cations the magnesium ion is found to be in rather smaller concentrations, whereas the calcium ion is abundant and fluctuates to a greater extent depending on the localities of hatcheries. The calcium ion is always present in nearly the same concentration as the bicarbonate ion. It will, accordingly, be predicted that the cation which forms silicates may be an alkaline metal.

2. *The Relationship between Chemical Composition of the Water and the Mortality of Young Rainbow Trout.*

The probable factors governing the mortality of young rainbow trout are the kinds of food used, the procedure of culture and the

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[9] Tomiyama and Watanabe, 1938. *Bull. Agric. Chem. Soc. Japan*, 14: 15.

[10] Tomiyama, 1938, *ibid.*, 13: 98; Tomiyama and Suetomi, 1938, *ibid.*, 13: 99.

[11] Tomiyama and Hosokawa. Not yet published.

TABLE 1.–CHEMICAL COMPOSITION OF WATERS USED IN VARIOUS HATCHERIES

Name of Hatchery	Source of Water	Water Temp.	pH	Total Solid mg/1	Hardness	Alkalinity	Cl mg/1	P_3 mg/1	SO_4 mg/1	SiO_2 mg/1	Ca mg/1	Mg mg/1
Samegai	spring	12·5	7·5	113	5·62	1·84	6·69	29·3	1·20	8·54	33·9	3·75
Akesina	spring river w.	16·8	6·6	113	4·19	1·07	6·44	16·6	8·54	20·3	20·7	5·58
Ogaki	spring	14·0	—	86·0	2·27	0·91	4·08	21·9	3·25	22·9	11·2	3·02
Nikuchi	spring	10·8	6·1	70·9	1·27	0·30	6·10	8·8	6·75	19·1	5·86	1·93
Fuji	spring	10·0	6·8	75·8	1·61	0·57	4·36	78·0	5·35	29·5	6·72	2·86
Sapporo	spring	16·5	6·4	94·9	2·00	0·47	11·1	14·2	9·45	33·0	9·76	2·73
Chitose	spring	8·5	6·6	105	1·32	0·54	6·84	16·7	7·10	45·4	5·84	2·15
Oizumi	spring	10·8	7·0	65·6	1·10	0·53	3·33	138	2·00	47·5	5·09	1·67
Aisaka	spring	11·6	6·5	166	2·75	0·72	13·9	29·0	7·50	45·1	11·8	4·71
Shiobara	spring	12·0	7·2	113	1·85	0·61	5·09	38·7	9·95	39·7	9·16	2·75
Egawa	river w. spring	20·0	6·5	62·3	2·45	0·57	4·51	8·2	6·76	14·6	11·1	3·86

TABLE 2.–MILLIGRAM EQUIVALENT OF CATIONS AND ANIONS IN HATCHERY WATERS

Name of Hatchery	^rCl	$^rSO_4$	$^rHCO_3$	$_4SiO_2$	$_4HCO_3+SiO_2$ % of anion	^{r}anion	^rCa	^rMg	^rCa Mg % of anion
Samegai	0·19	0·03	1·84	0·29	90·5	2·35	1·70	0·31	85·5
Akesina	0·18	0·18	1·07	0·68	83·0	2·11	1·03	0·46	70·7
Ogaki	0·12	0·07	0·91	0·76	89·7	1·86	0·56	0·25	43·5
Nikuchi	0·17	0·14	0·03	0·64	75·2	1·25	0·29	0·16	36·0
Fuji	0·12	0·11	0·57	0·98	87·0	1·78	0·34	0·24	32·5
Sapporo	0·31	0·20	0·47	1·10	75·5	2·08	0·49	0·23	34·6
Chitose	0·19	0·15	0·54	1·51	85·8	2·39	0·29	0·18	19·6
Oizumi	0·09	0·04	0·53	1·58	94·0	2·24	0·26	0·14	17·8
Shiobara	0·14	0·21	0·61	1·32	84·6	2·28	0·46	0·23	30·2
Egawa	0·13	0·14	0·57	0·47	79·6	1·33	0·55	0·32	65·2

quality of water. In Japan, similar foods have been used for rearing trout. Hence, if there is not much difference in the culture procedure, the quality of water will certainly influence the mortality of trout. Accordingly records have been collected from eight hatcheries which afford reliable data of mortality over a fairly long duration of rearing trout. The averages of the records are given in Table 3. It will be seen that the quality of water does not primarily influence the phase from egg to hatched fry, but it does influence the phase after beginning to take food.

TABLE 3.—THE MORTALITY AND RELATED DATA FOR RAINBOW TROUT AT VARIOUS HATCHERIES

Name of Hatchery	A*	B*	C*	D*	E*	F*	Per cent of dead fish in hatched fry coming up to surface water in the following month									Intensity of mortality
							1	2	3	4	5	6	8	9	12	
Samegai	1937, '39	3-4	1330	20	65	50			20						30	18
Akesina	1934-'37	4	1200	35	85	85	15	27				38			48	28
Ogaki	1937-'38	4	2500	57	82	78	7	25	41	45	48	48				33
Nikuchi	1936-'37	—					5	15	25	30	33	35			43	37
Fuji	1939-'40	4	2000	10	70	65	10	20	25	30					54	39
Sapporo	1941	4	1043	5	95	93	27	46	49							48
Chitose	1933-'34	4-5	731	—	85	81			31			59			66	63
Oizumi	1935, '37	4	2400		53	84	31	52	61	71		79				
	1938				66	73	30	38			53	57	61	62		

* A: Year when data were recorded; B: age of parent fish; C: average no. of eggs per fish; D: per cent unfertilized eggs; E: hatched eggs in per cent of fertilized eggs; F: yolk sac fry coming up to the surface as per cent of hatched eggs.

If the logarithm of the age in months of yolk sac fry which have come up to the surface and begun feeding is plotted against the logarithm of monthly mortality, a linear line characteristic of each hatchery is obtained. This line can be expressed by the following formula, namely, $M = \phi \log Z + b$, where Z is the age in months, M, mortality of trout during Z months, b, mortality within a month after yolk sac fry come to surface, ϕ, slope of the line. In discussing the problem of mortality, the value for ϕ is more reliable than the mortality at a certain time-period. So, ϕ is adopted for quantitative treatment of mortality and designated here as "intensity of mortality". The value for ϕ has been obtained from the graph, since the values of mortality at various hatcheries are not enough to be subject to the method of least squares.

Between the values for ϕ and the contents of silicate, a linear relationship holds as can be shown graphically. From the graph the following empirical formula has been obtained, namely $\phi = 1{\cdot}4\ [SiO_2] + 3$. The graph also shows that a negative correlation exists between the content of calcium and the intensity of mortality. The relationship can be expressed by an empirical formula: $\phi = -0{\cdot}74\ [Ca] + 43$. The last formula holds only when the silicate content of the water is less than 30 mg. per litre. When SiO_2 is greater than 30 mg. per litre, the ϕ-Ca relationship does not entirely conform to the formula. From the foregoing discussion it is clear that, in water rich in silicate and poor in calcium, the mortality is governed only by its silicate content. This conclusion will become apparent if comparisons of mortality be made among the waters in Nikuchi-, Fuji-, Oizumi-, and Chitose-hatchery. The mortality in Oizumi- and Chitose-hatchery is greater than Nikuchi- and Fuji-hatchery, although waters in these four hatcheries are nearly the same in calcium content. An explanation of this can only be made by recognizing the effect of silicate on the mortality to be exclusive in such a case where calcium content is low. From the foregoing consideration it can be emphasized that, besides temperature and quantity of water, determinations of silicate and calcium are indispensable to get an indication as to whether the water is suitable to the culture of trout. It appears that calcium may behave antagonistically against silicate. However, because the calcium content was always found to be inversely proportional to the silicate content, it is difficult to conclude which is the direct cause of mortality, lack of calcium or abundance of silicate. This may be elucidated through a further experimental study to be made on the effect upon the mortality of either adding silicate to water rich in calcium, or vice versa.

It is worthy of note in this connection that in Oizumi hatchery mortality decreased from 67 to 36 by using an improved food in 1938. The improvement was carried out by making fungi (*Aspergillus oryzae*) grow over the mixture of silk-worm pupae, rice bran and calcium phosphate. The improvement may be due partly to an increase in digestibility and vitamin content; nevertheless the effect of adding calcium phosphate must not be neglected.

Further study is needed to clear up the mechanism of effect of silicate or calcium upon the metabolism of the fish. So far as the present study goes, however, the following explanation may be postulated. Owing to the positive electric charge, calcium ions can penetrate into muscle tissue more easily than silicate ions since non-diffusible protein anions will predominate in the tissue. This phenomenon is quite probable from the experiment of Kaplanski and Boldirewa.[5] It will follow that silicate ions will accumulate more or less in the blood vessels, resulting in the disturbance of normal metabolism.

SUMMARY

(1) The water used in eleven trout hatcheries has been analyzed for most anions and most cations except sodium and potassium.

(2) The bicarbonate ion was always found to be inversely proportional to the silicate ion. The sum of both anions was found to amount to 75-94 per cent of the total anions.

(3) Alkaline metals seemed to form silicate since alkaline earth metals were found in nearly the same equivalent amount as the bicarbonate ion.

(4) A straight line was obtained when we plotted the monthly mortality of the fry against logarithm of age in months of yolk sac fry at the surface. The slope of the line, which is designated in this paper as intensity of mortality, is certainly more reliable than the mortality at a certain time-period.

(5) The values for the intensity of mortality at various hatcheries are directly proportional to the contents of silicate over a wide range (8-47 mg./1), and inversely proportional to the contents of calcium, provided that silicate is less than 30 mg./1. In water containing silicate greater than 30 mg./1, the silicate content exclusively governs the intensity of mortality.

(6) A probable mechanism of the effect of silicate upon the mortality is postulated.

A debt of gratitude is recorded to the late Professor S. Nakai of the Imperial Fisheries Institute for aid in collecting the sample waters and various accompanying data, and it is a pleasure to thank many hatcheries for their hearty co-operation with our work. Thanks are also extended for a grant from the Research Fund of the Ministry of Education.

SYMPOSIUM ON PROTECTION OF NATURE, TERRESTRIAL AND MARINE, AND CONSERVATION PROBLEMS OF THE PACIFIC AREA

REPORT OF THE STANDING COMMITTEE FOR PROTECTION OF NATURE

REPORT OF THE STANDING COMMITTEE FOR THE PROTECTION OF NATURE IN AND AROUND THE PACIFIC FOR THE YEARS 1939-1948

By C. Skottsberg, Chairman of the Standing Committee

Shortly after the close of the Sixth Congress, World War II broke out, and conservation was replaced by destruction, which must have made itself deeply felt in almost the entire Pacific region. It is easy to understand that conditions were unfavourable for collecting data on the status, from a nature protection viewpoint, of plant and animal life in Pacific islands, and that the work of the Committee was more or less completely suspended during the war. Soon after hostilities ceased I tried to secure information and, thanks to the interest taken in these matters by a number of people, some reports have been handed in, most of them, however, by persons outside the Committee.

After the death of Professor Miyoski in 1934, the chairmanship was vacant until the Committee met in Berkeley on July 29, 1939, when Dr. E. D. Merrill was appointed. At the close of the congress the Committee was composed as follows:

Chairman: Dr. E. D. Merrill, Arnold Arboretum, Jamaica Plain, Mass.
Secretary: Dr. C. Skottsberg, Botanical Garden, Gothenburg, Sweden.
Members for:
Australia—Dr. E. C. Andrews, Sydney, N.S.W.
Canada—Professor C. McLean Fraser, Dept. of Zoology, Vancouver, B.C.
China—Professor H. H. Hu, Fan Institute of Biology, Peiping.
France—Dr. Jules Rouch, Oceanographic Institute, Paris.
French Indo-China—Vacant.
Great Britain—Dr. C. M. Yonge, University of Bristol, England.
Hawaiian Islands, U.S.A.—Mr. E. H. Bryan, Bishop Museum, Honolulu, T.H.
Holland—Dr. P. van Tienhoven, Amsterdam.
Japan—Dr. T. Kaburaki, Imperial University, Tokyo.
Netherlands Indies—Dr. K. W. Dammerman, Buitenzorg, Java.
New Zealand—Dr. P. Marshall, Lower Hutt, N.Z.
Philippine Islands—Mr. D. B. Pagurigan, Bureau of Plant Industry, Manila.
Malaya—Vacant.
United States of America—Dr. Harold J. Coolidge, National Research Council, Washington, D.C.

It was not found necessary to fill the vacancy for Alaska. In the absence of Dr. Hu, Dr. Y. R. Chao served for China, and in the absence of Dr. van Tienhoven and Dr. Dammerman, Dr. H. J. Lam represented Holland and the Netherlands Indies.

Having been informed of the resignation of Dr. Merrill as chairman, I have, upon request, consented to act in his place until a new chairman has been appointed. In place of Dr. Marshall, who has resigned, I have asked Dr. H. H. Allan, Wellington, N.Z., to represent New Zealand.

Summary of Reports, given in answer to the Questionnaire (appendix), or otherwise:—

CHILE

The Republic of Chile is not represented on the Committee, and it is desirable that a representative be appointed. Meanwhile, Mr. G. Looser, Santiago, has continued to report on the progress of conservation of wild life in Chile. During the period after 1939, five new national parks have been created.

1. *National Park of Puyehue*; April 8, 1941.

The park is situated in the province of Valdivia and Orsorno and covers a stretch of land 100 metres wide on both sides of the international road leading to the outlet of Lago Puyehue and to the Termas de Puyehue, continuing to Paso Rincón on the Argentine frontier, further as a territory of 750,000 hectares between Lago Puyehue and the Argentine frontier, and Rio Gol-Gol-Lago Gris and a line from Paso Rincón to the outlet of Rio Nilque in Lago Puyehue. Most of the land is forested.

2. *National Park of Frai Jorge*; April 15, 1941.

Comprises 845 hectares of the Frai Jorge ridge, 424 of which are covered with forest. This is, however, only three-quarters of the forested area.

3. *National Park of Talinay*; March 29, 1945.

Includes 114 hectares on Cerro Talinay, 66 of which are forested. This mountain is the southern extension of the Frai Jorge range, or Talinay range as it is called on Chilean maps, an elevated portion of the Coast Cordillera. These isolated forest patches, composed mainly of *Aextoxicum punctatum*, are the northernmost forests in Chile and of very great phytogeographical interest. Both parks were created through expropriation of private property.

4. *National Park of Pirihueico*; April 14, 1945.

The park is in the province of Valdivia and comprises Lago Pirihueico and its surroundings, including several valleys and a triangular piece of territory along the Argentine boundary. In nature it is described as intact and of great scenic beauty.

5. *Cape Horn National Park*; April 25, 1945.

Includes Cape Horn and adjacent islands in the province of Magallanes. The Wollaston islands and the extreme south of Tierra del Fuego, extending north to Nassau Gulf fall within this area. The entire region is practically virgin, but it is to be regretted that no steps were taken to declare it a sanctuary before the most interesting and in many ways admirable Fuegian Indians had become exterminated.

By a decree of May 4, 1945, a National Commission for the Protection of Wild Life was created ("Comisión Nacional de Protección de Vida Silvestre"), directly under the Ministry of Agriculture. Whereas the various decrees by which the national parks were created lay stress on their importance as centres for tourism and recreation, and praise their scenic beauty, this document is styled in the spirit prevailing at the Washington Convention, May 1940, to which reference is expressly made, saying that "to protect the soil, the water, the forest, the flora and fauna and all the natural resources is to maintain the existence of the country". The Commission's aim will be to indicate the proper measures to be taken in order to establish an active protection for all the forms of wild life and their ecological medium and to preserve in their natural surroundings specimens of all indigenous species of plants and animals, including the migratory birds, etc. For this reason the Commission will make a systematic survey of all the existing national parks and reservations, natural monuments, bird sanctuaries, etc., and of districts which ought to be declared as such, and authorize biologists and other scientists to make corresponding explorations; further, it will organize an institute for biological investigations and, until this can be done, will use the existing university and other laboratories.

Evidently parks like Puyehue and Pirihueico do not correspond to the national parks in the United States, as they contain land privately owned. The proprietors are prohibited from clearing land by setting fire to the forest and are obliged to comply with the directions of the Ministry of Lands and Colonization with regard to the exploitation of their property; if no agreement can be reached on the basis of the regulations stipulated, expropriation will follow. Time will show how this system works.

Even if some of the recommendations passed by the Pacific Science Congresses in 1933 and 1939 did not have an immediate effect, the general idea that something had to be done was received with enthusiasm in scientific circles in Chile, and a campaign was started and supported by the press. We have seen the result in the creation of the parks mentioned above. One of the items of unique importance was the preservation of the Juan Fernadez islands and Easter Island, strongly recommended by the Vancouver meeting. These islands were declared National Parks in 1935. Unfortunately, a demand repeated by the Congress in 1939, namely that the goats should be exterminated, led to no result. It is to be hoped that the Science Society of Chile will keep this, and other demands not attended to, in mind.

It is not difficult to create national parks and to make laws and regulations, but when it comes to enforcing them and to provide the necessary funds, the troubles begin. In order to know how the Chilean park system worked, one of the men who has done most to rouse an interest for preservation of nature among his countrymen addressed the Inspector General de Parques Nacionales, asking him some questions. I think that his answers, given in the beginning of 1947, are sufficiently interesting to be quoted in full.

"1. *The budget?*—'There is no budget. Of the funds of the Forest Department an annuity varying between 100,000 and 200,000 pesos (a Chilean peso = 0·036 dollars) is allotted to the management of the parks. This sum is hardly sufficient for administrative work.'

2. *Number of functionaries in charge of the Parks?*—"Only one, the Inspector General. With money from the Forest Department 20 persons are paid, who have various titles, but work in the grounds. As no salaries are included in the National Budget, we have to pay them as labourers.'

3. *Have the measures adopted to prevent fires been effective?*—'After the two very bad years 1943 and 1944, an appreciable improvement has taken place. According to my opinion the measures themselves are not sufficiently effective, but in the general public and especially among the functionaries of the provinces a spirit of cooperation has been created which has become fruitful. Before we started the campaign against clearing land by fire, the newspapers, intendants and governors did not pay any attention at all to this problem; now articles are published months ahead (of the critical season, the dry summer) and the land owners are warned. Real sanctions (as provided for in the decrees) are rarely used, only fines; but the farmers fear publicity. There are also many who really understand the problem and assist us. On the whole, our interference has helped to develop a love of the trees and an understanding of their importance.'

4. *Scientific collecting?*—'Anybody can collect with the permission of the Administrator. As the number of functionaries is too small, there is no real control and in reality nobody asks permission. Naturalists are, however, very few, so that until now a strict control has not been necessary.'

5. *Camping and camp fires?*—'It is permitted to camp and to build a fire. Very few people have availed themselves of this permission and the number of excursionists does not amount to half a dozen per park in one year.'

6. *Rights of the people living in the parks?*—'According to law it is prohibited to cut trees, or clear the ground, unless permission has been granted in every special case by the Forest Department. This in case the land has not been expropriated.'

7. *Boundaries and fences?*—'Conditions are rather anarchical in this respect. Generally the boundaries are formed by natural barriers such as rivers, lakes and mountain ranges. Fences do not exist even along one-tenth of the boundary lines, and they are, in many cases, the old ones existing before land was expropriated to form the park. Moreover, they are of very different type.'

"Having answered your questions, I shall add that there are many projects with regard to the National Parks and that in the Agricultural Plan funds with this object have been discussed, but so far there is no organization with authority and responsibility. The Minister of Lands and Colonization is at liberty to destroy or break up the National Parks and there is no law that protects the lands declared parks. Such things have happened many times. In accordance with their political interests ministers have given away or sold pieces of National Parks."

This sounds very strange. Evidently, Nature Preservation will have a long way to go before stable conditions have been attained.

SAN FELIX AND SAN AMBROSIO

The two small, rocky islands, known as the Desventuradas Group, are situated in Lat. S 26° 16′-18′ and Long. W. 79° 57′-80° 7′, about 500 miles west of the mainland of Chile which, in these latitudes (26° 16′-19′ S. L.) is very dry and almost desert-like in the coast region. San Felix is little more than a rock about 600 feet high, with very scanty vegetation and inhabited by seabirds. San Ambrosio is about 1,575 feet high, enough to collect some moisture, and the crest is more or less covered with vegetation. No scientist has ever visited San Ambrosio. but the flora is fairly well known thanks to collections made on different occasions by sailors who managed to climb to the summit. In 1937 I published a Flora of the islands, based on a collection made in 1896 by a Chilean naval party and first studied by the late Professor F. Johow, who had left a manuscript which was entrusted to me; and recently another, much smaller collection enabled me to make certain additions. A larger collection was brought back a couple of years ago, and I have a report that it contains species not found by earlier visitors. The flora is poor; but extremely interesting and unique in its way; of the 21 flowering plants known, 14 do not grow anywhere else, and four belong to three endemic genera.

Occasionally fishermen have visited these waters to catch the large langost occurring also at Juan Fernandez but not along the coast of the mainland, but as the islands themselves offer absolutely nothing that could be of any use, and moreover being inaccessible and lacking water, nobody would believe that their scanty wild life might be threatened with destruction. However, two years ago two fishermen settled on San Ambrosio at the entrance of the narrow ravine which offers the only, still very difficult, access to the summit, and after a while they introduced goats. This means that the unique flora is doomed, if the islands are not declared a National Park and the goats removed. As all victuals must be brought from outside, weeds are certain to spread; there was, as far as we know, not a single introduced plant before. Our committee has good reason to pay attention to these alarming facts.

French Oceania

It is to be regretted that the many islands under French rule have not been represented on our Committee by some resident scientist or at least by somebody who is familiar with the region and aware of the destruction still going on. The Berkeley Congress passed a resolution recommending various steps that should be taken but it is easily understood that attention would be deflected from such matters during the period 1939-46.

New Caledonia

(A. Guillaumin)

Dr. Guillaumin, one of the directors of the National Museum of Natural History in Paris and the foremost authority on the flora of New Caledonia, has been very helpful in answering my questions with regard to the actual conditions and needs as far as wild life is concerned.

1. The greater part of the mountainous areas of the island is still covered with primitive vegetation.

2. The principal types are dense forests, open forests and, on the summits of the ranges and in the areas consisting of serpentine, brushwood.

3. The cultivated areas are rather restricted and, due to the configuration of the country, not much likely to become extended.

4. Of introduced animals, a species of deer has become naturalized and has multiplied to such an extent that the possibility of utilizing it to make canned meat has been discussed.

5. Among the weeds is *Lantana camara*, introduced on purpose as an ornamental plant.

6. There are many valuable timbers which are exploited. Many of the very best kinds are local, form only small stands, and regenerate slowly. The conifers such as the species of *Agathis* (kauri pine), the *Araucarias* and *Callitropsis araucarioides*, as well as *Spermolepis gummifera* are among the trees which need protection.

7. Nothing.

8. No reforestation at all has been attempted.

9. Yes, especially among the trees now cut without any kind of regulations. The native sandalwood (*Santalum neocaledonicum*) deserves to be mentioned here.

10. The aboriginal races destroyed the vegetation by clearing the land for their rather extensive cultivations, but in many places the result has been a kind of equilibrium between man, his animals and the plant cover. It is the so-called civilized peoples, especially the whites, who with their ever-growing demands have become a terrible menace to the original flora.

11. Beside the lumber industry, mining is important on account of the very valuable minerals found, such as nickel, chrome and cobalt. Plantations are of only slight importance.

12-22. A special report on the natives is expected.

23. Nothing.

24. –

25. –

26. –

27. –

28. –

29. –

30. Certainly not.

31. Yes.

32. There may be difficulties. An old project to create forest reserves was opposed by the mining companies and subsequently dropped.

33. Yes.

34. No answer.

35. Probably not.

36. Commercial collecting should not be encouraged.

37. Yes, several institutions are interested.

GALAPAGOS ISLANDS

Ever since Darwin's days these islands have been the object of very great interest, but unfortunately this has not prevented destruction through the direct activity of man and of animals introduced by him and run wild. The result has been disastrous, especially for the unique giant tortoises, some species having become extinct before they were properly known to science and the rest being on the verge of extinction. So great is the interest in their preservation that both the American Committee of Wild Life Protection and the British Association for the Advancement of Science have created special Galápagos subcommittees. In my report to the Fifth Pacific Congress in 1933, a series of answers to my questions gave a good idea of the conditions some 15 or 20 years ago. At that time, the tortoises were protected by law, but the law not being enforced, no improvement was noticed, and no reservations had been established. The Fifth Congress strongly recommended the preservation of wild life in these islands. In 1934 the islands, with the exception of the major part of Isabela (Albermarle) were declared a national park, and the regulations are very strict indeed. An incident quoted in my report to the Sixth Congress showed, however, that protection is illusory as long as the law is not taken seriously even by the Ecuadorians themselves.

Recently I received additional information on the Galápagos Islands from Dr. J. T. Howell and Dr. J. R. Slevin of the California Academy of Sciences. Their answers to my questions are given below.

1. About 90 per cent (this figure is surprisingly high with regard to the facts stated under 4, but it is probably meant that only 10 per cent are under cultivation).

2. Brushwood, with or without large cacti, form the most extensive types of vegetation; forest and grassland are developed locally.

3. No.

4. Cattle are found on Chatham, Charles and Albemarle, asses on Albemarle, James, Charles and Indefatigable, goats on South Seymour, Barrington, James, Charles and Hood, pigs on James and Charles, cats on Chatham, Charles and Albemarle, and rats on Charles, Indefatigable, Duncan, Chatham and Narborough, and no doubt also on the other islands. As can be seen, Charles Island is well provided. (Dogs not mentioned, but they are on two islands, Charles and Indefatigable, at least—see Report, 1933, p. 406.)

5. *Psidium guayava* and *Citrus limonia* are the most important.

6. Some (kind not known to us) is cut for local use (house-building, fencing, etc.).

7. No.

8. No.

9. The tortoises on all islands, land iguanas (*Conolophus subcristatus*) on Barrington, Albemarle and South Seymour.

10. All the people are more or less white.

11. In Report, 1933, p. 407. Dried fish is exported from Indefatigable (and perhaps from other islands), a small amount of sugar and coffee from Chathams, and a small number of cow hides from Albemarle.

13. Less than 500 Ecuadorians.

14. Perhaps 50 Europeans and Americans.

15-22. Do not apply.

23. (a) The islands were set aside as game sanctuaries (see above). (b) There is a special law regulating preservation (see above). (c) Animals protected are listed in the Official Register, Executive Power, No. 607. No plants are mentioned. (d) Nothing.

24. See above.

25. Apparently all kinds of country represented.

26. There is no kind of management.

27. No, only the regulations bearing on the fauna.

28. The supervision of the game law lies with the authorities on Chatham Island, where visitors are obliged to report. Special permits are required to visit the islands.

29. Not yet known.

30-31. Do not apply.

32. Not at all. (Probably to some extent, if part of grazing lands are closed for cattle.)

33. We doubt if control of introduced animals would be possible.
34. Impossible.
35. Perhaps desirable. (This has already been done.)
36. Yes.
37. No.

Recently Albemarle Island was made a convict settlement, and the Swedish Deep Sea Expedition on board the *Albatross*, which had permission to make investigations on the islands, was expressly warned not to attempt to land on Albemarle, where the naturalists had planned to study the region above the timberline, best represented on this island, the highest in the group.

HAWAIIAN ISLANDS

After my visit to the Hawaiian Islands in 1938 I included in my Report to the 1939 Congress a series of remarks on the urgent need for protection of the natural flora and fauna. I have always found it hard to understand that, in these islands, which are richer than any other archipelago in peculiar forms of life and which, moreover, with its famous Bishop Museum, its large and modern university, its experimental stations, etc., are the undisputed scientific centre of the Pacific, so little has been done to preserve the flora and fauna. Anybody who takes the trouble to see for himself cannot but find that the Hawaiian National Park is inadequate. It is only thanks to the absolute necessity to protect the watersheds that, with the exception of Lanai, considerable areas of natural or seminatural forest still exist, because further destruction would have threatened the watersupply and thus been harmful to the economic interests of the plantations. Where destruction had been going on without harming such interests, it continued, I gave eloquent examples of this. The Standing Committee, convinced that something had to be done, and done soon, passed a series of resolutions which were referred to the Committee of Resolutions. From this they emerged in a very crippled state, but still contained some definite recommendations. Among the items stressed by the Standing Committee but left out in the final wording, was the plea for the formation of a local society for the preservation of wild life in Hawaii. In January, 1940, I had a letter from the representative for Hawaii on the Committee, Mr. E. H. Bryan, who explains why this proposal had been dropped. He was of the opinion that "there are already too many societies which should have the protection of wild life as one of their objectives; that officialdom pays little or no attention to any of these existing organizations; and that what we need is some correlating group, with an official standing, which can advise the government and help to shape public opinion". His idea was to approach the Governor of Hawaii, who was known to be very sympathetic toward conservation, and to suggest that he appoint an official advisory committee to the government; this committee would try to shape public opinion toward a sympathy and enthusiasm for protection wherever needed. He concludes: "I believe that if we can both get the official ear, and arouse public interest, we can go far toward conserving what is left of our native environment".

I quite agree: an official Office for the Protection of Nature is urgently needed. It must be provided with sufficient public funds. But there is no better way of arousing public interest than to round up all persons who really love native Hawaii and understand that every loss of a native species of plant or animal is irreparable and is a loss not only to Hawaii but to the whole world, and to form an active society which has conservation as its sole objective. Members will join from all islands, every island should have its local committee, meeting regularly to listen to lectures on the plant and animal life and to reports of members engaged in survey work. The main objectives will be to investigate the status of the various species known to have become rare and supposed to be threatened with extinction, to visit old localities for rare species and find out whether they still exist or not, and to furnish the Office of Nature Protection with exact dates. There is nothing to prevent this office from consulting one or several of the many organizations which, in the words of Mr. Bryan, "should have the protection of wild life as one of their objectives". There are many private landowners or employees of plantation companies who would be willing to become members of a nature protection society and to co-operate effectively. Education is necessary here as everywhere; there are many, too, who, even if they love the beautiful Hawaiian plants, have no idea of what they mean to science in general. My advice is: don't depend on the lame interest shown by all kinds of organizations formed with different goals and objectives and to which conservation is a matter of secondary importance, turn to the general public, educate it and make it the guardian of Nature's treasures! I would not emphasize this if I did not know that it can be done and that it is the only way of collecting the information needed before definite steps can be taken. I have followed the conservation movement in the Scandinavian countries, in Finland, Poland, Germany before the war, Switzerland, etc., and everywhere the local bodies form the basis on which the entire movement rests, and their effort to engage the government has been crowned with success.[1]

With regard to the official advisory committee suggested by Mr. Bryan, I don't believe it was ever appointed, and to judge from what is happening now I suppose that we are farther from the establishment of such a committee than ever.

In 1948 I spent another two half months in the islands engaged in botanical work. All islands except Niihau and, of course, Kahoolawe, where landing is prohibited, were visited. I was able to make a comparison between 1938 and 1948.

Kauai. New roads had been built in the mountains, making some areas more easily accessible. As a result, the number of weeds had increased all along the roads and trails, and the stands of young koa are much invaded. The trail from the automobile road to Mohihi, ascending to Lehua Makanoe had been widened part of the way and is passable for a jeep for a couple of miles. The trail from the end of this road could hardly be recognized, as it is now so completely overrun with weeds that very soon little will be left of the original flora. Large areas of the high land in the north-west have been utterly ruined and erosion is setting in, but some native shrubs are still abundant.

Oahu. I did not visit the Waianae Range, but it is not probable that the situation has improved. After Pearl Harbour an observation post was erected on Kaala, the highest summit in Oahu, and a unique spot from a botanical viewpoint. Whether or not is caused the extermination of endemic species, some of which do not occur elsewhere, I cannot tell. Abandoned military camps were visited on other islands. Even if as little ground as possible—and generally in stands mostly formed by introduced trees—had been cleared, the camp sites have, of course, become centres for weeds which spread from there in all directions.

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[1] See also Hoogerwerf's report on the Netherlands Indies!

Molokai. The forest did not seem to have suffered much during the war, even if no portion can be said to be quite free from introduced elements. Along roads and trails in the mountains an increase of the weeds was noticeable.

Maui. The same localities as in 1938 were visited in West Maui. No further encroachment on the Puu Kukui summit bog had been made, but the damage is done. The lobeliaceous flora around Haelaau was still good, but is threatened by a kind of blackberry which has been planted (?) and is spreading rapidly. It is one of the most noxious weeds and very difficult to get rid of when once established.

Of the original plant cover on the isthmus practically nothing is left now. Part of the National Park was visited with the special object of looking for the Haleakala sandalwood. Mr. D. Fleming of Lahaina had told me that he knew of a single tree which he supposed was the last one (outside the crater at least); this tree was found. Material for fixing the road had been dumped on this spot, a few feet from the base of the stem, forming a rather unsuitable background to the tree and offering a strange sight in a national park.

Lanai. As is well known, very little of the native flora is left on this island. If only the ground turned into pine-apple fields or used for grazing had been stripped of its plant cover, little could be said, but of the rainforest on the high ridge the greater part has been destroyed and such foreign plants as *Araucarias, Cordyline australis, Eucalyptus, Leptospermum scoparium*, etc., have changed the picture entirely. The strip of native forest left is very narrow. In the low north-west portion of the island are found the last sad remnants of a dry forest of great interest, once the home of the endemic Lanai sandalwood. The whole region is ravaged by cattle. In the ground cover, which is very poor, not a single native plant is left. All the trees are old and many were dying, and not a single seedling is allowed to spring up. Two sandalwood trees had been located, and thanks to the assistance of Mr. J. Munro, they were found. According to him they are the last. Possibly it will be too late now to save this forest by fencing for the soil must have undergone considerable change. All the land along the north coast outside the plantations offers a terrible sight; here and there in the ravines are a few native trees, but weeds have the dominance everywhere, and erosion is working at full force, carrying away the surface soil with its open plant cover.

Hawaii. The forests on the Kohala Mountains will perhaps recover since cattle have been excluded, and in the summit region weeds were scarce or even absent. Wild pigs are, however, very plentiful and do considerable damage. The summit itself is not, as Rock believed, inhabited by an open bog, nor by a bog forest; the *Sphagnum* bogs, which are of great interest and have their equivalent in the islands only on Mount Eke (West Maui), cover parts of the east slope, extending in places down to the Upper Hamakua ditch trail, which is little used now; the houses, which were in tolerably good condition in 1938, have been removed or are falling to pieces. The horse-trail leading from Waimea village to the ditch trail had been widened to a road; thereby the station for a local endemic species, known only from this place, had been destroyed, and there was no sign of the plant. Weeds had spread along the ditch-trail, and the palms observed a short distance inland had disappeared, but the region is still a refuge for a number of interesting endemics, species of *Labordia, Stenogyne, Phyllostegia, Lobelia, Trematolobelia, Clermontia, Cyanea, Dubautia,* and others.

Of the native vegetation along the west and north sides of Kohala practically nothing is left. Of the koaia forest (*Acacia koaia*) only a few old trees still linger and not a single seedling could be found. As far as I know this is the last stand of koaia. The whole area is grazing land, but even grazing, here as in the coast region to the south, is seriously threatened by the rapid spread of *Opuntia*. Driving along the motor-road to Mahukona, Upolu and Kapaau hardly a single Hawaiian plant is seen; not even the beach flora is left.

The forest on the slope of Hualalai toward Puuwaawaa, famous for its many rare trees since the time of Rock, who discovered several new species here, was visited by me in 1922. Rock had foreseen its sad fate, if not a sufficiently large area was fenced in to keep the cattle out, but though I found it in a rather bad state, and there was no possibility for natural reproduction, *Kokia Rockii* and *Hibiscadelphus hualalaiensis* were still represented by a number of good specimens, and of the peculiar unifoliolate *Sophora,* the type tree—apparently the only specimen found—still existed. In 1948 there was little left of anything except the commonest trees, *Sophora* was gone, of *Kokia* one tree was located and the last four specimens of *Hibiscadelphus*, forming a small group, had been fenced in; but unless seedlings spring up. also this species will soon share the fate of its congeners, which are extinct. And this is, like *Kokia,* an endemic genus.

The Cross Road over the saddle between Mauna Kea and Mauna Loa offers excellent possibilities for a biological study of a region which has been little accessible. Along the road a considerable number of weeds have sprung up, but so far only annuals, which do little harm. The mamani forest with its park-like stands of mamani (*Sophora chrysophylla*) and naio (*Myoporum sandwicense*) is better developed around and below Pohakuloa than anywhere else where I have seen it, and as a considerable section of the country has been fenced off, this seems to be a suitable site for a national park with facilities for winter-sports and hunting, as already offered by the Pohakuloa Camp.

The National Park around Kilauea was in more or less the same state as ten years ago, if not poorer; along the roads introduced ornamentals were even more conspicuous. Mr. G. O. Fagerlund has compiled a list of introduced species (1947). Many of these exotics, nearly 400 species and varieties altogether, are confined to gardens and not likely to invade the mountain forest. Some, of a more dangerous nature, easily take charge of disturbed areas.

In 1938, a fair-sized tract of virgin forest covered the east slope of Mauna Kea, rich in large koa trees and with scattered groups of the endemic palm *Pritchardia beccariana,* and it was expected that this forest, the last good one in this island, would be left untouched. However, I learnt to my surprise that this forest now was the site of a prison camp, called Kulani, and that the koa was going to be cut on a large scale in order to create a profitable territorial lumber industry. Whether this unfortunate scheme includes reforesting with koa, I do not know. Anyhow, the supply will soon be exhausted. I visited the place, where large clearings had been made and the camp was in full swing. A motor road leading to the camp, which is closed to visitors not holding permission to enter, had been constructed and extended through the forest as far as to the 1942 lava flow. Once disturbed, the forest will soon become invaded by foreign elements, and the natural undergrowth, exposed to light, cannot persist. I doubt that this region has even been thoroughly explored by an expert botanist. I got the impression that the whole scheme was strongly disapproved by the forestry people, but they were unable to stop it. It is a hard blow to nature protection in the islands.

NATURE PROTECTION IN THE INDONESIAN ARCHIPELAGO (NETHERLANDS INDIES)

By A. Hoogerwerf, Member of the Council of the Society for Nature Protection in the Netherlands Indies

1. *Introduction.* (Something about the past of our movement in the Netherlands Indies and some hopes for the future). Although in the early part of 1900 Government regulations came into force to protect certain animals and to limit game-hunting in this Archipelago, it may be pointed out that not until 1912 did the foundation of the Netherlands Indian Association for Nature Protection induce the authorities to pay more attention to the cultural duty they had to fulfil on behalf of matters connected with Nature Protection and Game-Hunting.

This Association was established at Buitenzorg and counted among its members prominent citizens of this country, among whom were several biologists of standing, and had as a member of its Council the Director of the Botanic Gardens. Owing to the last fact this scientific institution was more or less the centre of the activities in this domain during the whole history of the movement of Nature Protection in the Netherlands Indies.

Immediately after its establishment this association proposed to the Government the composition of a series of new laws regarding protection of nature, through which it became possible to keep certain areas of zoological, botanical, geological or aesthetic importance untouched and to protect certain species of animals. This shows that the pioneer work in our Archipelago in this respect has been done principally by this private association, which during its whole existence enjoyed the moral support and co-operation of the authorities, with the Governor-General of the Netherlands Indies as its patron. In later years it also co-operated with the Netherlands Committee for International Nature Protection — with its well-known chairman Dr. P. van Tienhoven—and kept up relations with many sister societies abroad. The annual reports of the association bear witness of its important work on behalf of the protection of nature in the Netherlands Indies.

About the year 1930 the work concerning the preservation of nature had become so extensive that the authorities deemed it necessary to make the whole movement a Government matter. They charged the Director of the Botanic Gardens—in addition to his own functions—with this work and with a large part of matters pertaining to game-laws.

However, it soon became impossible for this functionary to carry out so great a task, with the result that, in 1935, a special official had to be appointed, who in the same year was put at the disposal of the Director of the Botanic Gardens. He was the first official to work in this branch exclusively, and up to 1947 he remained alone. In 1947, however, the situation improved, after the proposals of the Director of the Botanic Gardens, Prof. Dr. L. G. M. Baas Becking, were accepted, and two more specialists may be appointed, viz. one botanist and one game-warden.

The total area of the reserved territories in the whole Archipelago amounted at that period to about 1,500,000 ha., with more than 120 different objects. For Java only this area was about 122,000 ha., consisting of about 70 preserves, enlarged by more than 50,000 ha. at the beginning of the Pacific War.

When making laws to protect the treasures of Nature in this unique Archipelago, much attention was paid to the protection of certain species of animals, such as rhino, orang-utan, tapir, hogdeer, elephant, Komodo monitor, birds of paradise, etc., etc., which may not be killed, caught or exported without a special licence. The export of all living mammals in numbers greater than two specimens and of more than five birds at a time is also prohibited. In case of damage to plantations by protected animals or by so-called "game", special licences may be granted for killing or catching.

The importance of game-hunting in Java before the war may be shown by the fact that more than 60,000 hunting-rifles were in circulation and that every year about 9,000 licences were bought, with a revenue of about 850,000 Dutch guilders.

Unfortunately, however, only a very small part of this amount could be spent for matters concerning nature protection or the protection of our game, especially our big game, as will be shown below.

Maintenance and supervision of all Fauna- and Nature-Reserves in this Archipelago fall under the Forestry Service as these areas lie either within the permanent forest reserves or in other places directly under the jurisdiction of this Service. It was natural and efficient to entrust the care for these preserved areas to the foresters.

The Forestry Service was charged by a Government decree ("Ordonnantie") with the control of the reserves, which implied that adequate measures were to be taken by this Service to prevent destruction of or damage to protected areas, and their maintenance in the best possible way. If it is realized—as pointed out above—that the protected territories in Java occupy in total an area of about 175,000 ha. (440,000 acres) divided over about 70 different sites and situated all over the island, it needs no explanation that a satisfactory supervision involves a rather extensive organization. A staff of trained men and a certain amount of money are essential.

Notwithstanding these obvious requirements, the Forestry Service has never established an office or division for Nature Protection and the total amount of funds granted before the outbreak of the war was undeniably too low. The protection of nature received therefore too little attention, which in my opinion was due more to the policy followed by the Government than to neglect by the Head of the Forestry Service. However, this is of no immediate concern.

As regards the Department of Civil Affairs which had to look after the control of all regulations beyond the powers of the Forest Department, the situation was similar, with the result that the laws remained dead scraps of paper with scarcely any practical effect.

The voice of the officer for Nature Protection was advisory only, not authoritative and, in practice, the Director of the Botanic Gardens could have no real influence upon the line of action (or non-activity!) followed by the Forestry Service and the other authorities.

It is essential to understand that the Director of the Botanic Gardens at Buitenzorg, the centre of scientific research in this Archipelago, who is assisted by a staff of specialists in the field of Natural Sciences, is one of the very few authorities who can judge the desirability of preservation of certain areas and of protection of certain species of animals. He receives direct and competent advice as to the best way of maintaining the perishable treasures of nature, now rapidly disappearing before the ever-extending cultivation. It is a pity, in the opinion of everybody interested in this field of science, that this authority has not more influence in the development of the protection of nature than up to the present time.

It is evident that a policy as outlined above could never yield favourable results, all the more as no funds were granted to the Botanic Gardens to be spent on this matter wherever the Forestry Service failed through lack of funds.

This situation roused considerable opposition in circles concerned with Nature Protection: among the members of the Netherlands Committee for International Protection of Nature, the Netherlands Indian Association for Nature Protection, the Botanic Gardens, etc.

The character of the Forestry Service in this Archipelago is economic; it is bound to follow a policy of economic profit in the first place, whereas the protection of nature aims at scientific and, in general, non-economic interests: leading principles for the preservation of the treasures of nature for posterity.

An increase of authority for the Director of the Botanic Gardens is urgently and badly required in order to improve this situation. It seems to be the keystone of any effective organization.

The central office which should carry this authority logically belongs not in the Forestry Service, but should be entirely in the hands of the Botanic Gardens, while in the future it even might be entrusted to a special department with its own personnel and budget.

One might be inclined to believe that no revenues make good the money spent in the protection of nature, and short-sighted persons have thought that expenses on behalf of Nature Protection are wasted money. This is erroneous.

Under normal circumstances—which, however, have not been established yet in this Archipelago—the revenue received from licences for fire-arms, hunting licences, etc., are approximately 850,000 florins annually. This amount would be sufficient to cover all costs involved in a good Service for the Protection of Nature and such protection is essential if any hunting, exportation of animals, etc., is in future desired. This simple truth has never been seriously considered by the highest authorities in this country. The difference between the large revenues from hunting licences and the scanty expenditure for Nature Protection is a constant annoyance, in spite of the fact that game hunting and catching of protected animals (with a licence) in the territories beyond Java are free of any cost, even the export not being charged for.

I have tried to demonstrate above that the revenues to be expected from hunting licences, export permits, etc., will cover all expenditure now required to maintain Nature Protection. But, if any revenue may be expected in the future at all, it is necessary to guard the existing Reserves and to look seriously after our game and rare species of birds and animals. This should be done quickly and thoroughly, to stop poaching by the native population and provide for other unaccountable influences tending towards the exterminating of all kinds of game and of useful vegetation.

I need not explain here the importance of the Fauna- and Nature-Reserves from a scientific point of view. Especially after a war, which annihilated so many irreplaceable objects of beauty or interest, we must realize that these aspects of nature should be protected as a matter of duty for later generations.

When the protection of nature in the Indonesian Archipelago is—*and it must be*—reorganized, the Director of the Botanic Gardens or the Head of the proposed organization of Natural Sciences should have an important say in the following:

(a) To grant and to determine the funds to be spent for nature protection;
(b) the best way of spending the funds;
(c) the selection of personnel to be employed;
(d) the work to be carried out.

I have spoken above of a planned organization of Natural Sciences, because since the war proposals have been made to found Scientific Research, whether pure or applied, and it has also been suggested that this organization should include matters concerning Nature Protection, Game Hunting Regulations, etc., etc., which would be entrusted to a special division.

If these projects could be realized, this would mean considerable progress, not only because in this case all interests concerning Nature Protection would be put into "one hand", but also because in this way it might be possible *to prevent these important matters being entrusted to the Governments of the different, more or less independent States,* into which the Netherlands Indies will be broken up in the future. Regarding the very important economic and other problems which must be solved by these States, we may be assured that Nature Protection will not occur in their working programme for many years to come.

When finally there is time to pay attention to the preservation of the unique flora and fauna of the Indonesian Archipelago it might be too late in many respects. During more than two miserable years after the Japanese capitulation, I myself had the opportunity to see how astoundingly quickly plants and animals are pushed back or destroyed by so dense a population as that of Java. In the Indonesian Archipelago there is "periculum in mora" and I appeal to all who are interested in international Nature Protection, in particular the newly established "Union Internationale pour la Protection de la Nature", to help the handful of enthusiasts in that part of the world.

2. *Nature Protection during the Japanese Occupation* (1942-1945) *and after that Period.* The Dutch official for Nature Protection, A. Hoogerwerf, resumed work in April, 1942, but he was removed to the ornithological section of the Zoological Museum in February, 1944, and therefore his activities on behalf of Nature Protection were restricted to a minimum. The work had to be limited to Java only, as no contact with the other islands could be obtained. With a lot of trouble some excursions could be made, but this stopped altogether after August, 1943. The Rhino Reserve, Udjung Kulon and the Nature Reserves, Pulau Duwa, Tjibodas Mt. Gede and Depok were visited. Udjung Kulon was inspected in September-October, 1942, and for the second and last time in January, 1943. In September this Fauna Reserve and its game seemed to be safe, but there was hardly any personnel left and guarding was done very insufficiently. After this visit more funds were put at the disposal of the Bantam forester as a result of which in January, 1943, things were improving, the guarding was again satisfactory, and activities on new pastures had started again. During the whole Japanese occupation the guards remained at their posts and reports were favourable. It appeared that the Nature Reserve Pulau Duwa was deprived of its taller vegetation, which made it impossible for the heron- and stork-like birds to nest here. Guards were appointed again and some months later prospects seemed already much better. In this reserve, too, the guards stayed till the Japanese capitulated. The Nature Reserve Depok was only little damaged and the newly appointed guard remained on his post during all the war years. It was only *after* the Japanese capitulation that this reserve was very heavily damaged and nearly deprived of all its big, very old trees.

The Nature Reserve Tjibodas Mt. Gede was slightly damaged, but in general it remained in good condition during the whole occupation.

About some other reserved areas, e.g. Mt. Papandajan, Tangkoeban Prahoe-Pelaboehan Ratoe unfavourable reports reached our office, from which it became evident that these territories had been heavily damaged.

The many attempts to get the private Reserve Tjikepoeh under Government control failed, and owing to this the big game there may have been nearly or entirely exterminated.

From Central- and East-Java only few reports came in.

The Yang Highland had been guarded by Mr. Ledeboer Sr. himself and after his internment (during which he died) by his son, probably until Japan's capitulation. Some thousands of deer were shot there on behalf of the Japanese army, although this is of only small importance considering the big deer supply in this private reserve. The Fauna Reserve Baluran kept its guards during the whole occupation. In June, 1944, the number of bantengs (wild oxen) was estimated at about 500, the deer at 200. The waterholes for the game were cleaned and deepened in 1943. Favourable reports arrived from the Nature Reserve Ardjuna Lalidjiwo, where the game-supply was said to improve.

All efforts to induce the authorities to take measures against poaching, which seemed easily to be possible with a Police organization such as the Kempetai (Japanese Gestapo), had none or only a very small result. It was, however, a favourable circumstance that nobody, except members of the army and some other private Japanese, was permitted to have a gun or other firearms. But everyone knows that in this country a poacher—even without a gun—can easily succeed in laying hands on any wild animal which he wants for food. It may be expected that the game beyond the reserves has badly suffered as a result of intensive poaching and probably this is also the case—perhaps to a smaller degree—with the game within the reserved areas.

One shudders at the very thought of poachers entering our Fauna Reserve with modern automatic guns. . . . Or at the probable results of the fact that the "terrorists" believe that certain parts of a rhino give invulnerability to the bearer (so-called Djimat). We can only be extremely pessimistic about the position of our game and our last specimens of *Rhinoceros sondaicus*, as we are still not able to visit this reserve, and nearly all other reserved areas, owing to the chaotic situation still prevailing.

3. *List of Fauna- and Nature-Reserves in the Indonesian Archipelago.*

Number	Name	Situated in	District	Area in ha.
1	Prinsen-Eiland	West-Java	Pandeglang	17,500
2	Udjung-Kulon	,,	,,	37,500
3	Pulau-Duwa	,,	Serang	8
4	Danoe-lake	,,	,,	2,500
5	Tjikepoeh	,,	Soekaboemi	10,000
6	Klein Kombuis	,,	Batavia	18
7	Depok	,,	Buitenzorg	6
8	Angkeh	,,	Batavia	15
9	Poelau-Ramboet (Middelburg)	,,	,,	20
10	Artjadomas	,,	Tjiandjoer	2
11	Takokeh	,,	Soekaboemi	50
12	Tangkoebanprahoe-Palaboehanratoe	,,	,,	22
13	Soekawajana-Palaboehanratoe	,,	,,	33
14	Tjadas-Malang	,,	,,	21
15	Tjimoengkat	,,	Tjiandjoer	56
16	Tjibodas (Mt. Gedeh)	,,	,,	1,040
17	Tjibanteng	,,	,,	447
18	Doengoes-Iwoel	,,	Soekaboemi	9
19	Malabar	,,	Bandoeng	5·8
20	Junghuhn-Monument	,,	,,	?
21	Tjigenteng-Tjipanje I/II	,,	,,	2 and 8
22	Tomo	,,	Soemedang	1
23	Koorders Monument (Pendjaloe)	,,	Tjiamis	16
24	Telaga-Patengan	,,	Bandoeng	150
25	Papandajan-crater	,,	,,	844
26	Telaga-Bodas	,,	Garoet	285
27	Penandjoeng (Pangandaran)	,,	,,	457
28	Peson-Soebah I/II	Central-Java	Batang	each 10
29	Oeloelanang-Ketjoeboeng	,,	,,	71
30	Goetji	,,	Pekalongan	?
31	Telaga-Randjeng	,,	,,	?
32	Moga	,,	,,	?
33	Tjoeroeg-Bengwawah	,,	,,	?
34	Getas	,,	Semarang	?
35	Geboengan (Mt. Oengaran)	,,	Salatiga	1·8
36	Sepakoeng (Mt. Telamojo)	,,	,,	2·5
37	Pagerwoenoeng-Daroepana	,,	Kendal	30

Number	Name	Situated in	District	Area in ha.
38	Tjabak I/II	,,	Toeban	3 and 9
39	Keling I/III	,,	Rembang	60
40	North-Noesa-Kambangan I/II	,,	Tjilatjap	293
41	East-Noesa-Kambangan	,,	,,	277
42	Diëng Plateau	,,	Bandjarnegoro	85
43	Pringombo I/II	,,	Magelang	12 and 46
44	Nglirip-grotto	,,	Bodjonegoro	?
45	Mt. Pitjis	East-Java	Ponorogo	32
46	Mt. Sigogor	,,	,,	200
47	Klangoen-Saraden	,,	Madioen	5 and 1
48	Besowo-Gadoengan	,,	Kediri	7
49	Manggis-Gadoengan	,,	,,	12
50	Tengger-Sandsea	,,	Malang	5,250
51	Ranoe-Koembolo	,,	,,	1,342
52	Ranoe-Pani-Regoeloe	,,	,,	96
53	Ardjoeno-Lalidjiwo	,,	,,	580
54	Mt. Abang	,,	Pasoeroean	50
55	Danau-Darangan	,,	Loemadjang	380
56	Poeloe-Sempoe	,,	Malang	877
57	Soengi-Kolboe	,,	Bondowoso	9
58	Wetangan-Poeger I/IV	,,	Djember	each 2-4
59	Tjoromanis-Sempolan I/VIII	,,	Banjoewangi	each 2
60	Rogodjampi I/II	,,	,,	17 and 8·5
61	Pantjoer-Idjen I/II	,,	,,	4
62	Tjeding	East-Java	Bondowoso	2
63	Noesa-Baroeng	,,	Djember	6,100
64	South-Banjoewangi	,,	Banjoewangi	62,000
65	Kawah-Idjen	,,	Bondowoso	2,560
66	Saobi (Kangean)	,,	Pamekasan	430
67	Baloeran	,,	Sitoebondo	25,000
68	Bawean (Poelau-Noko and -Noesa)	,,	Soerabaja	15
			Total area	176,801·6

SUMATRA

Number	Name	Situated in	District	Area in ha.
1	Rafflesia-Reserve Atjeh I/II	North-Sumatra	Atjeh	?
2	Mt. Löser	,,	,,	416,500
3	Wilhelmina-chaine	,,	Langkat	200,000
4	Dolok-Saoet	Central-Sumatra	Tapanoeli	39
5	Baringin-Sati	Sum. Westcoast	Pandang Pandjang	0·01
6	Anai-Crevice	,,	,, ,,	211
7	Peak of Indrapoera (Kerintji)	,,	Solok-Kerintji	12,500
8	Batang-Paloepoeh	,,	Agam	3·40
9	Rimbopanti	,,	,,	3,500
10	Harau-Crevice	,,	Pajakoemboeh	298
11	Sibolangit	Sum. Eastcoast	Deli	115
12	Dolok-Tinggiradja	,,	Simeloengoen	167
13	Batoe-Gadjah	,,	,,	
14	Lau-Deboek-Deboek	,,	Karoe Highland	7
15	Batoe-Ginoerit	,,	Bilah	0·50
16	Rafflesia-Reserves I/III	South-Sumatra	Benkoelen	71
17	Rafflesia-Reserves, Despetah I/II	,,	,,	0·31
18	Rafflesia-Reserves, Tjawang I/II	,,	,,	0·20
19	Doesoen-Besar	,,	,,	12
20	South-Sumatra	,,	Benkoelen/ Lampongs	356,800
21	Krakatau and Verlaten Niland	,,	Lampongs	2,500
22	Way-Kambas	,,	,,	130,000
23	Oeloe-Tiangko-grotto	,,	Djambi	?
24	Berbak	,,	,,	190,000
25	Boengamas-Kikim	,,	Palembang	1
			Total area	1,312,756·42

Number	Name	Situated in	District	Area in ha.
		BORNEO		
1	Mandor	West-Borneo	Mandor	195
2	Lo-Pat-Foen-Pi	,,	Singkawang	8
3	Mt. Paloeng	,,	Simpang	30,000
4	Padang-Loewai	South-east Borneo	Koetei	1,000
5	Koetei	,,	,,	306,000
6	Kotawaringin	,,	Kotawaringin	100,000
7	Sampit	,,	Sampit	205,000
			Total area	642,283
		CELEBES		
1	G. Lokon	North-Celebes	Menado	100
2	G. Tangkoko-Datoe-angoes	,,	,,	4,146
3	Tanggala	,,	,,	125
4	Panoea	,,	Gorontalo	1,500
5	Mas-Popaja-Radja	,,	,,	160
6	Bantimoeroeng	South-Celebes	Makassar	10
7	Nopabalano (Moena)	,,	Nopabalano	9
			Total area	6,350
		OTHER ISLANDS		
1	Sangehh	Bali	Badoeng	9·8
2	Mt. Rindjani	Central Lombok	Bajan	40,000
3	Padar-Rintjah	Timor	Manggarai	?
4	Mt. Api	Moluccas	Island Gn. Api, Banda-sea	?
5	Rumphius-Monument	,,	Amboina	2·5
6	Lorentz	,,	New Guinea	320,000
			Total area	360,012·3

TOTAL NUMBER AND AREA OF THE FAUNA- AND NATURE-RESERVES IN THE INDONESIAN ARCHIPELAGO.

	Number of objects		Area
Java	68	more than	176,800 ha
Sumatra	25	more than	1,312,756 ha
Borneo	7	about	642,283 ha
Celebes	7	about	6,350 ha
Other islands	6	more than	360,012 ha
Total:	113	more than	2,498,201 ha

4. *Review of all Regulations concerning Nature Protection and Game Hunting.*

A. Nature Protection

1. Wild Animal Protection Ordinance 1931 (protection of wild animals and birds).
2. Regulations in virtue of the Articles I and 3 (Paragraph 3) of the Wild Animal Protection Ordinance 1931.
3. Nature Protection Decree 1941 (regulations concerning Fauna- and Nature-Reserves).

B. Game Hunting

1. Hunting Ordinance for Java and Madura 1940.

2. Hunting Regulations Java and Madura 1940, to carry into execution the Hunting Ordinance 1940.

5. *Regulations About to come into Force when the Pacific War Broke Out*

The following Ordinances and executive Regulations were ready to be presented to the Government of the Netherlands Indies when the Pacific War broke out.

1. Fauna Protection Ordinance valid for the whole Archipelago.
1a. Regulations to carry into execution this Ordinance.
2. Hunting Ordinance for the territories outside the islands of Java and Madura.
2a. Regulations to carry into execution this Ordinance.

With the coming into force of these new laws the "Wild Animal Protection Ordinance and Regulations 1931" (as mentioned above) would expire.

NEW ZEALAND

Dr. H. H. Allan, Wellington, has kindly submitted for publication the following report on areas created scenic or historic reserves during the period 1938-1947.

1938. 61,868 acres. In addition, two private scenic reserves, 519 acres. Additions made to Bream Head Reserve at the entrance to Whangarei Harbour. Rock Pinnacles of Manaia were declared a reservation. A scenic reserve was established along the Kiretere-Awakino Road. At Lake Rotoma 484 acres of dense forest were set aside. Various small forest and mountain areas in North Island were also reserved.

In South Island 28,200 acres in the Lewis Pass area, Nelson Land District, and 3,396 acres along Arnold River, Lake Brunner, Westland. There is now a chain of reserves round Lake Wapaho, Westland. Some 1,147 acres were added to the reserves near the Fox Glacier, and a number of smaller reserves were established in various parts of South Island.

1939. 16,905 acres.—Near Awakino, North Island, 382 acres of forest. Some 10 acres added to Trounson Kauri Park. On the Kaimai Ranges, Auckland, 4,490 acres of forest. Additions were made to the Huiarau Reserve, Gisborne Land District. The whole of the old Maori fighting pas are now included. A number of forest areas along roads in South Island, including areas in the Marlborough Sounds.

1940. 5,951 acres.—A number of areas, mainly forested, were reserved in both islands. An area of 88 acres surrounding Shakespeare Cliff, Cook's Bay, Coromandel Peninsula, was proclaimed a reserve, being the site of Captain Cook's observation of the transit of Mercury. Further areas were reserved in the Marlborough Sounds, totalling 1,200 acres. The area surrounding the Opiti Blowhole at Jack's Bay, Otago. Major P. H. Johnston set aside a forest area of over 200 acres on his estate at Raincliff, South Canterbury, as a memorial to the pioneers, to be called "Raincliff Pioneer Park". The dominant tree is the kahikatea, *Podocarpus dacrydioides*.

1941. 16,184 acres.—Reservation was completed over 653 acres on Great Barrier Island, including kauri and mixed forest. An area of 13 acres in the Petone Borough, Wellington, was reserved to preserve what is known as Percy's Gardens, including the old mill building and waterwheel of the Percy family. Reservations were completed over 1,409 acres at Deep Bay, Pelorus Sound. An area of 4,612 acres was reserved at the Maruia Hot Springs, Nelson District, South Island. Some 1,550 acres were added to the Pelorus Scenic Reserve, Marlborough Land District.

1942. 1,890 acres, including 708 acres around Silvan Lake in the Dart District, Otago. Two small areas were reserved near the Kennedy's Bush Reserve, Summit Road, Banks Peninsula, one by donation of Sir H. Rhodes.

1943. 6,800 acres, including 4,066 acres in the Mangamuka Gorge, North Auckland. This contains fine forest and has an excellent panoramic view from the main highway.

1944. 143 acres and, further, a gift of 218 acres by Mr. J. W. Hayes in the Kaeo Parish, North Auckland, including a forested area and a bold rocky hill. A small area on which stands the Canterbury Women's Pioneer Memorial was transferred to the Crown. The memorial commemorates the pioneer women of Canterbury, who passed over this spot when journeying from Lyttelton over the Port Hills to the plains.

1945. 64,000 acres in various parts of the Dominion. Some 650 acres alongside the Mangamuka Gorge were added to this reservation. Some 62,200 acres were set aside along the new Haast Pass Road. The area, mainly in excellent southern beech forest, extends from a few miles above Lake Wanaka to the summit of the range.

This year a coastal area of 38,000 acres on the western side of Tasman Bay was created "Abel Tasman Park", the official opening ceremony being performed by the Governor-General, Sir Cyril Newall. The ceremony was attended by the Netherlands Legation, headed by Dr. Charles van der Plas. Torrent Bay, which is backed by the forest-clad hills of the Park, was the anchorage of D'Urville in 1827.

1946. 2,012 acres.—This included 1,623 acres near Picton, Queen Charlotte Sound.

1947. 6,538 acres.—An area of 148 acres was added to the Trounson Kauri Park. Forest land of 929 acres was reserved in the Waikanae District, Wellington, and considerable additions were made to reserves in the Queen Charlotte Sounds area, totalling 2,042 acres.

In the Scenery Preservation Report for 1947 it is stated that the number of scenic reservations stood at 1,220, covering 920,760 acres.

PHILIPPINE ISLANDS

Recently two reports have come in. Dr. Arthur F. Fisher, Director of the Natural History Museum, San Diego, Cal., formerly Director of the Bureau of Forestry in Manila, sent me the following answers to my questions, and also put me in touch with his successor in the Philippines.

1. About 50 per cent.
2. Virgin forest, cut-over forest, open forest grassland, mangrove swamps. *Nipa* swamps, congon land (*Imperata*). See *Bur. For. Bull.* 10.
3. Yes.
4. Yes.

5. Yes.

6. About 400 species of native timber enter the markets.

7. Much afforestation and reforestation is carried on.

8. Yes, *Swietenia* spp., *Toona* spp., *Cedrela* spp., *Leucaena glauca*, several Indo-Malayan useful woods, and wattles (*Acacia*) from Australia for the production of tannin, etc.

9. Species of *Canarium* and *Diospyros*, *Maba buxifolia*, some orchids.

10. In both.

11. Principal natural resources are lumbering, mining, fishing and water power. Main cultivations rice, cane, coconuts, yams, sweet potatoes, citrus and other fruits, legumes.

12. Around 16 million.

13. Around 50,000, including American Army and Navy.

14. Chinese about 150,000, other Asiatics 2,000.

15. Increased at the rate of 2½ per cent before World War II.

16. No answer except that the natives are smaller than Europeans, averaging about 5 ft. 4 in. in height and 110 lbs. in weight.

17. About one million lead a primitive life.

18. Many laws; some reservations have been established especially for Negritos.

19. The old Roman Catholics a great deal. Modern Protestant missionaries with school system greatly influenced diet and sanitation.

20. There is no need for efforts to save the natives.

21. The more primitive tribes retain cultural elements and implements of their own make.

22. Much has been done to further native artistic talents and native industry.

23. (a) There are many forest reserves, areas for protection of wild life, and national monuments. (c) Special laws for Tamarao in reservations in Mindoro. (d) Many forest products are under license, as are also mines and fisheries.

24. Area total about two million hectares in permanent reservations; lands in public domain much greater, all under restrictive use laws.

25. All permanent forest reservations exhibit various types of natural vegetation.

26. Primarily managed by the Bureau of Forestry. Parks and reservations guarded by rangers and game wardens.

27. Yes.

28. Yes.

29. No answer, but presumably yes.

30. Does not apply.

31. Yes.

32. Only in case population pressure increases.

33. Does not apply.

34. Water hyacinth very obnoxious to lakes and rice-fields and costly to destroy with copper sulphate.

35. License system is imposed to check excessive collecting.

36. Commercial collecting should be drastically supervised, especially for orchids.

37. Yes, a National Museum, universities, and the National Research Council. The Bureaus of Science of Forestry, of Lands, etc., are all interested in preservation of wild life.

The Chairman of the N.R.C., Dr. B. M. Gonzalez, requested the Director of the Bureau of Forestry, Florencio Tamesis, Chairman of the Division of Agriculture and Forestry of the N.R.C., to prepare a report, which follows.

1. The total land area of the Philippine Islands is 29,740,972 hectares (114,875 square miles), of which 17,496,192 hectares (67,579 square miles) or 59 per cent are still covered with natural forest. In addition to this, there are 5,203,620 hectares (20,099 square miles) of grassland, some of which may be suitable for grazing purposes and to be reforested, and 606,812 hectares (2,344 square miles) of mangrove and fresh-water swamps.

2. The principal types of forest are dipterocarp forest (75 per cent of the virgin forest), *Vitex parviflora* forest, mangrove forest, beach forest and mossy forest. See also 1.

3. Yes, as shown by the following figures for cultivated lands: 1903, 2,827,704; 1918, 4,563,723; and 1939, 6,690,593 hectares.

4. Cattle are generally kept in pastures, while goats and pigs are domesticated animals. Rats are under control and damage considered negligible. Wild game abounds but is not destructive.

5. Yes, for example *Lantana camara, Eupatorium* sp., *Mimosa pudica* and *Eichhornia crassipes* (water hyacinth).

6. Many kinds of native timber are cut for export and/or local use. The principal are: A. For export. (1) "Philippine Mahogany" (trade name): (a) Red M., including Tanguile (*Shorea polysperma*) and Red Lauan (*S. negrosensis*); (b) Light red M., including White Lauan (*Pentacme contorta*), Almon (*Shorea almon*), Bagtican (*Parashorea plicata*) and Mayapis (*Shorea squamata*); (2) Dao (*Dracontomelum dao*) for cabinet and veneer work; (3) other species like Narra (*Pterocarpus* spp.) Apitong (*Dipterocarpus grandiflora*) and Palosapis (*Anisoptera thurifera*). Mostly for cabinet and veneer. B. For local use. (1) Philippine Mahogany (dipterocarp family), as mentioned above; (2) many other species, the greater bulk of which are Ipil (*Intsia bijuga*), Narra (*Pterocarpus* spp.) Tindalo (*Pahudia rhomboidea*), Banuyo (*Wallaceodendron celebicum*), Molave (*Vitex parviflora*), Palosapis, Manggachapuil (*Hopea acuminata*), Makassim (*Syzygium Benthamii*), Lanete (*Wrightia laniti*), Yakal (*Shorea gisok*), Guigo (*Shorea guiso*), Apitong, Narig (*Vatica mangachapui*), Malugai (*Pomatia pinnata*) and Gubas (*Endospermum peltatum*).

7. Yes. The Bureau of Forestry has been exerting efforts since 1912 to reforest barren and grass lands, especially those on the watersheds of destructive rivers, by planting forest tree species suitable for this purpose. The work, interrupted during the war, was resumed after liberation; and reforestation is now laid on an extensive development plan. Among the indigenous species doing well in our plantations, containing an area of about 26,000 hectares, are Narra, Molave, Banaba (*Lagerstroemia speciosa*), Baguilumbang (*Aleurites moluccana*), and Tindalo.

8. Yes, some; the principal ones, which are very promising, are mahogany (*Swietenia macrophylla*), teak (*Tectona grandis*) and *Cedrela odorata*.

9. Of plants the Molave, one of the best for construction purposes (especially house posts) and railroad ties, has been in great demand since time immemorial. Its possible extermination has been prevented

by protective measures enforced together with regulations in connection with forest utilization. Studies are being conducted on the methods of propagation of this and other species, so that the proper conservation of the principal commercial trees is taken care of.

The tamarao (*Bubalus mindorensis*), the deer or "usa" (*Rusa* spp.) and some birds have been reduced in number, but special laws and regulations aim at their conservation.

10. The destruction of the plants and animals mentioned has been chiefly due to the activities of the native population.

11. Forests, game, fish, minerals and water power. The main cultivated plants are coconut, abaca, rice, cane, tobacco, corn and some fruit trees.

12. According to the census of 1939, 15,833,649 Filipinos.

13. Total 16,169 (1939); Americans 8,709, Spaniards 4,627, Germans 1,149, Britishers 1,053, Russians 237, France and Holland 197 each.

14. Chinese 117,487, Japanese 290,757, others 3,941 (1939).

15. Increasing. There were about seven million in 1903, 15·8 million in 1939.

16. The natives are medium-sized, well-built and sturdy and can endure hard work.

17. A relatively small group, barely one half per cent of the total population, locally known as "Non-Christians", lives a more or less primitive life.

18. Certainly not necessary. The natives constitute an independent, self-governing body in a democratic country.

19. On the distinct Non-Christian tribe known as "Negritos" the influence of missionaries has been very slight. With this exception, the missionaries have had a great influence on native culture and religion. In fact, the Philippines are the only Christian nation in the Far East with Western culture which began as early as 1571. The University of Santa Tomás, one of the leading institutions of learning in the country, was founded in 1611 by the Dominican Order.

20. Does not apply; see under 15.

21. Certainly, but they easily learn to use also the most modern implements and machinery.

22. The government is exerting every effort to encourage native arts and industries, which have developed considerably.

23. (a) Areas containing certain species of useful trees and native animal life needing protection are reserved. Example: The Liguasan Marsh Game Refuge and Bird Sanctuary in the Province of Cotabato, acc. to law, Act. 2590. National Parks are also established in accordance with Act. 3915, National Parks Law. See also under 24. Section 1826 of the Revised Administrative Code and Forest Regulations provides for creating forest reserves. Examples: Pambaran Forest Reserve, because of its good stand of Buri palm (*Corypha elata*) and Eucalyptus forest Reserve in Cotabato, containing a pure stand of Bagras (*Eucalyptus deglupta*). (b) Act 2590 as amended by Acts 2666, 3730 and 4005, entitled "Act for the Protection of Game and Fish". Forestry Circular No. 100, May 12, 1939, entitled "Enforcement of the provisions of Act 2590, as amended. Fish and game Administrative

Order 5, Sept. 26, 1934, entitled "Close seasons for certain species of birds and mammals". Act 3915, entitled "Act Providing for the Establishing of National Parks", declaring such parks as Game Refuges and for other purposes. To serve as Game Refuges and Bird Sanctuaries are national parks, botanical gardens, public parks, public school sites, public playgrounds, government experiment and breeding stations, government seed farms, public building sites, government nurseries, communal forests, communal pastures, cemeteries, and all other public lands and forests within a radius of one kilometre from any government rest house. (c) Of animals, the following are protected: Mouse deer (*Tragulus* spp.), tamarao (*Bubalus mindorensis*), deer (*Rusa* spp.), squirrels (*Nannosciurus* spp.), and lemurs (*Cynocephalus* spp.); painted snipes (*Scolopax* spp.) and all species of plovers (*Charadrius*), ducks (*Anas* spp.), pigeons (*Carpophaga* spp.), doves except barren ground dove (*Columba striata*), all species of coots (*Fulica)*, gallinules (*Porphyrio* spp.) and rails (*Rallus* spp.), all hornbills (*Anthracoceros*), pheasant (*Polyplectron napoleonis*), and mound builders (*Megapodius* spp.), and about 90 species of the other birds. Of plants: Act 2812, prohibiting the cutting of certain trees as durian, mangosteen, alupag (*Euphoria didyma*), bulala (*Nephelium mutabile*), the fruits of which are edible. Act 3572 prohibits the cutting of tindalo (*Pahudia rhomboidea*), akle (*Albizzia acle*) and molave (*Vitex parviflora*) less than 60 cm. in diameter measured at a height of 1·3 m. above ground. Act 3983 protects certain wild plants. Special Regulations governing the collection, possession, transportation, sale or export of protected species such as all *Phalaenopsis, Vanda, Dendrobium* and others (d) Laws and regulations such as Acta 3915, 3674, 3572, 2812, 3983, etc., limit the utilization of natural resources to the Philippines; see also above.

24. At present there are 101 Forest Reserves, covering 1,166,755 hectares; 33 National Parks, 226,142 hectares; 1,864 Communal Forests, 254,385 hectares; and 94 Communal Pastures, 19274 hectares. All these have also been declared game refuges and bird sanctuaries.

25. The present national parks contain various types of vegetation and animal life, peculiar geological formations, hot springs, caverns, subterranean rivers, beautiful waterfalls, natural swimming pools, etc.

26. The National Parks are closed to commercial exploitation, except in cases where diseased, dead or dying trees and silvicultural requirements, including undesirable species, demand the removal of such trees. If cutting is allowed, special licenses may be issued for the purpose under restrictions and closely supervised selection system and timber marking in order to minimize disturbing the natural wilderness and beauty. The timber in forest reserves is subject to commercial utilization and exploitation under very restrictive regulations in order to conserve the forest and insure its natural regeneration. The timber in the communal forests is utilized only for personal use of the residents of municipalities for which communal forests have been established under regulations with similar objectives as those for forest reserves.

27. See above. There are also special Quarantine and Pest Control laws.

28. The Bureau of Forestry. Supervision is effected by foresters, forest rangers and forest guards. Practically the entire Department of

Agriculture and Natural Resources enforces the nature protection laws and regulations with the assistance of the other branches of the Government, if necessary.

29. Yes.

30. As shown above, every available means for the protection of nature is taken.

31. Does not apply in this case; see above.

32. Protection measures, so far taken, do not interfere with the legitimate interests of either the white or the native population.

33-37. No answers. (These questions were, however, answered by Dr. Fisher; see his report.)

Appendix

Questionnaire regarding information wanted:

1. To what extent is the country still covered by natural vegetation and tolerably free from imported plants run wild or from weeds?
2. Which are the principal types of original vegetation (closed forest, open forest, brushwood, grass-land, etc.)?
3. Do the cultivated areas tend to increase?
4. Do goats, pigs, cattle, rats, etc., run wild over the country?
5. Are there any notable weeds acting as pests and encroaching on the native vegetation?
6. What kinds of wild timber are cut for local use or for export?
7. Has anything been done to reforest waste land by propagating and planting indigenous species?
8. Are imported tree species used for reforestation and which are the principal kinds?
9. Are there any remarkable plant or animal species threatened with destruction and what kinds?
10. Does the reason for this destruction lie in the activity of the native or of the white population?
11. Which are the principal natural resources and cultivations?

Population

12. Number of natives?
13. Number of white population?
14. Number of other foreigners (Orientals, etc.)?
15. Is the number of natives increasing, decreasing or stationary?
16. Physical status of the natives?
17. Do any of the natives lead a more or less primitive life?
18. What measures have been taken to protect the natives from abuse?
19. What influence have missionaries had on the native culture?
20. Is it possible that serious efforts to save the natives from extermination would meet with success or is it too late to do anything?
21. Do the natives still retain some cultural elements and implements of their own make?
22. In case the original cultural elements are of artistic value, require skilled labour and thus enrich aboriginal life, has anything been done to encourage native industry?

Nature Protection

23. What has been done to protect nature by
    (a) setting aside reservations?
    (b) prohibiting the destruction of wild life in general?

(c) id. of certain animal or plant species, and which?
(d) regulating the making use of natural resources of economic value?

24. Position, size, and character of national and private reservations?

25. To what extent do the present reservations exhibit the various types of natural or at least semi-natural country?

26. Management of national reservations?

27. Is there a nature protection law in existence?

28. Are the laws or other permanent or temporary regulations enforced by some kind of supervisor or park ranger?

29. Has the protection thus given proved satisfactory?

30. If nothing has been done in the way of nature protection, is it too late now to try and save the still existing remnants of wild life?

31. Does the region reported on include any piece of ground (part of island, small uninhabited island, etc.) suitable for reservation?

32. To what extent would protection measures interfere with the legitimate interests of the white and of the native population?

33. Could anything be done to prevent or to lessen the damage caused by introduced animals, without interfering unduly with the interests of the natives?

34. Will it be possible, without large expenditure, to check dangerous weeds?

35. Is it desirable or even necessary to introduce some kind of license system in order to limit excessive collecting for scientific purposes?

36. The future of private collections is sometimes uncertain. Would it be wise to stop such collecting, especially if made for commercial purposes?

37. Is there, in the region reported on, a local museum or a scientific society interested in nature preservation?

REPORT OF THE UNITED STATES MEMBER OF THE STANDING COMMITTEE FOR THE PROTECTION OF NATURE IN AND AROUND THE PACIFIC

By Harold J. Coolidge, Pacific Science Board, National Research Council, Washington, D.C.

Anyone who looks back over the Proceedings of previous Pacific Science Congresses and has a serious interest in problems of "Nature Protection" in the Pacific area should find satisfaction in the recommendations that have resulted from the symposia devoted to this subject, particularly at the Fifth Pacific Science Congress in June, 1933, where a declaration of principles was made which should serve as an inspiration and future guide to all of us:

"In view of the fact that the plant and animal world of many Pacific Islands is threatened with rapid destruction not only through actions which are controlled by the respective governments, such as the extension of cultivation, but also through unlimited collecting, uncritically encouraged by scientific institutions, it be resolved that such institutions be invited to co-operate in the limitation of collecting specimens so as to avoid covering the same field repeatedly only for the purpose of enriching the collections of every museum. . ."[1]

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[1] Quoted in the proceedings of the Fifth Pacific Science Congress – p. 385.

There is a strong tendency in modern thinking to consider resolutions made some years ago as dated or perhaps behind the times. Instead they were often ahead of their own times and were directed towards a future which we are now in the middle of. Perhaps we should select certain recommendations and re-enact them at each Congress to emphasize their importance and make sure that they are never forgotten.

There is a movement in the United States to develop, particularly throughout the west, a Conservation Pledge which states:

> "I give my pledge to advance peace through the conservation of the earth's living resources of wildlife, forest, grassland, soil and water, and to save from waste its oil and mineral wealth."[3]

If this should be widely adopted and carry with it the same sort of meaning as the Pledge of Allegiance to the National Flag, it would help in one phase of public education towards stimulating a wider interest in and understanding of Conservation.

A survey of reports of the various members of the Standing Committee on the Protection of Nature in and around the Pacific at past Congresses shows no definite pattern but rather "57 different varieties". Perhaps it is better that way, although I feel that if the representative from each country could present a summary of high points in the developments and progress that has been made in the Conservation of Renewable Natural Resources, and we classify soil as very much of a renewable resource, it would enable this Committee to be more effective in achieving the results that are of such concern to all of us. These reports might also make special reference to action that has been taken to follow out specific recommendations of the Pacific Science Congresses in the field of International Conservation.

Almost ten years have gone by since the Sixth Pacific Science Congress, and in the United States encouraging progress in many phases of Nature Protection has been made through the efforts of private individuals and private organizations, as well as municipal, state, and federal agencies. In fact there is a great deal to report!

Perhaps the most significant advances have been made through the work of four constructive Conservation agencies of our Federal Government: The Fish and Wildlife Service, the National Park Service, the Forest Service, and the Soil Conservation Service, all of whom have sent delegates to this Congress and prepared special reports, on request, which will form part of the overall report of the American member of your Standing Committee. I regret that the Reclamation Service is not also represented.

The report on the United States is made up of the following papers from Government sources—

Fish and Wildlife Service:

1. Conserving the Alaska Fur Seals: by Victor Scheffer.
2. Fluctuations of the United States big game populations during the last decade: by Neil Hosley.
3. Management of Migratory Waterfowl: by Clarence Cottam and Cecil Williams.

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[3] Douglas Wade, Transactions of the Thirteenth North American Wildlife Conference, St. Louis, U.S.A., March, 1948. — p. 158.

4. The Federal programme with relation to future development of Pacific fisheries: by Milner Schaefer.

Soil Conservation Service:

5. Scientific Soil Conservation: by H. H. Bennett.

National Parks Service:

6. Conserving Wildlife in the National Parks: by Victor Cahalane.
7. Some Conservation Problems in Hawaii National Park: by F. R. Oberhansley.

The Forest Service:

8. Progress in Forestry in the United States: by Lyle F. Watts.

From private sources—

9. Progress in management of large mammals with special reference to the wapiti in Jackson Hole; by Olaus J. Murie.
10. A Conservation Programme for Micronesia: by F. Raymond Fosberg.
11. Save-the-Redwoods: by Wallace Walter Atwood.

I wish at this time to express my gratitude to all those who have assisted in the U.S. report by preparing reports giving you information on various conservation activities in the United States and in the Trust Territory of the Pacific Islands, which we are administering under a mandate from the United Nations.

Before going on to the rest of the report I would like to make a half-dozen suggestions for your consideration:

1. That we consider establishing a general pattern for reports at future Congresses from the actual members of the Standing Committee on Nature Protection.

2. That we consider adding to this Committee representatives of the U.N. specialized agencies such as the FAO, UNESCO and WHO, who are most concerned with international activities in the field of conservation as distinguished from the national aspects which could be covered by the present membership. I should also like to see a representative of the recently formed International Union for the Protection of Nature included as a member of the Committee. It might be appropriate to ask the Pacific representative on the Executive Board of the Union, when he is chosen to be the Union's representative on the Standing Committee.

3. I hope that a way may be found to enable this Committee to belong to the International Union. This will require an annual contribution of 200 Swiss francs or about 50 dollars. If this expense cannot be met by the Pacific Science Association, I propose that it be raised by the Committee.

4. There is constant confusion of terminology in discussing such subjects as the Protection of Nature. In order to clarify what we mean, and I am sure that you will all agree that we should define this subject in its broadest terms, I propose that we adopt the definition which was set forth in the preamble of the Constitution of the IUPN and arrived at after careful deliberation. The term "Protection of Nature" is defined as "the preservation of the entire world biotic community, or man's natural environment, which includes the earth's renewable

natural resources of which it is composed, and on which rests the foundation of human civilization". Whenever "Protection of Nature" is mentioned in a Union document or report it is put in quotation marks which refer back to the above definition. I think the Committee should adopt this practice.

5. The name of this Committee is too long and cumbersome, and the Committee has proposed that it be shortened and that it be called the "Pacific Conservation Committee".

6. We are all concerned with the possibility of preserving the last remnants of endemic flora and fauna, particularly on small Pacific Islands. In this connection, Dr. Elton of Oxford has suggested to me that "It might help a good deal if in some future report you could give a table showing the number and approximate total areas of island groups, how many islands in each, and what per cent are (a) inhabited, (b) uninhabited—but spoiled by earlier action, (c) still 'virgin'. This would offset a certain impression of over-simplicity and would emphasize the staggering variety and complexity of these archipelagos." Some of this type of information has been assembled through the questionnaire but not, to my knowledge, compiled as yet on a comparative basis. Why shouldn't this make a good project for a joint operation by our Committee and the IUPN office in Brussels? It will require assistance from all who are here.

Finally, I feel that we should recognize that there is one person who is primarily responsible for the accomplishments in Pacific Conservation of the Standing Committee for the Protection of Nature. We cannot give him enough credit for the task that he has carried out so effectively and in a large measure single-handed, during his many years of service as the permanent secretary of this Committee, and as a climax to this long service Dr. Skottsberg is serving as Chairman of this Committee at the Seventh Pacific Science Congress. He is one who well deserves the honour of being one of the few distinguished guests invited by the Royal Society of New Zealand to attend this Congress.

CONSERVING THE ALASKA FUR SEALS

By Victor B. Scheffer, United States Fish and Wildlife Service

A group of volcanic rocks—the Pribilof Islands in the Bering Sea—are today the centre of an industry representing a capital investment of 100 million dollars. These islands are the summer home of the Alaska fur seals.* In conserving the fur seal herd the United States Government has been privileged to set a classic example of wildlife management. We appreciate this opportunity to discuss the welfare of the seal industry and to speculate upon its future development.

The Alaska fur seals number several million. Each summer the United States Government harvests a crop of seal skins, taking for this purpose about three-fourths of the current three-year male class. The value of the harvest is about three million dollars a year (Table 1). The Canadian Government is allotted one-fifth of the annual pelt harvest under terms of an international agreement.

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* *Callorhinus ursinus.*

TABLE 1.—IMPORTANCE OF THE FUR SEAL INDUSTRY OF THE PRIBILOF ISLANDS, ALASKA, DURING THE TEN-YEAR PERIOD 1939-1948.[1]

Year	Seals Killed	Finished Skins Sold[2]	
	Number	Number	Value Dollars
1939	60,473	43,071	823,885·90
1940	65,263	60,294	1,247,230·62
1941	95,013	62,788	2,343,319·11
1942[3]	145	51,892	1,499,496·87
1943	117,164	38,850	1,744,803·65
1944	47,652	44,676	1,634,749·25
1945	76,964	46,380	2,401,894·75
1946	64,523	54,675	3,850,539·50
1947	61,447	48,712	2,607,507·50
1948	70,142	52,326	3,422,290·75
Total[4]	658,786	503,664	21,575,717·90

[1] In addition to fur seal skins the following by-products were sold during the ten-year period (approximately): 2,750 tons of seal meal valued at 262,000 dollars, and 1,441 tons of seal oil valued at 233,000 dollars. (7·5 pounds of seal oil equal 1 gallon.)

[2] From seals killed a year or more earlier.

[3] Sealing interrupted by World War II.

[4] There is no direct relationship between the number of seals killed and the number of skins sold in the same year because Canada, under treaty provisions, receives 20 per cent as her share of the annual take, and, in addition, there is a lag in time in the processing of the skins.

THE PRESENT FRAMEWORK OF CONSERVATION

The fur seals are, from one point of view, a livestock and from another, a fishery. We tend to think of seals as livestock and we use the term "herd". Perhaps there is a better word to describe this group of amphibious, migratory, fish-eating furbearers.

The United States Fish and Wildlife Service is now primarily responsible for the welfare of the seal herd and for the success of the annual harvest. A private agency under contract to the United States Government, the Fouke Fur Company, is primarily responsible for curing and processing our share of the raw skins. A certain number of finished, dyed skins are sold twice yearly at a public auction in St. Louis, Missouri.

To establish the fur seal industry on a sustained yield basis the Russians as early as 1799, and later the Americans, found it necessary to adopt certain policies. In order of importance they were obliged to (1) restrict the total number of seals killed, (2) confine the kill to male seals, (3) restrict the kill to male seals of a single age (about 3 years), (4) carry out the kill in a selected season of the year, and (5) utilize the waste products. Consideration has been given to these points in detail as follows:

1. The limit on the number of seals to be killed each summer is not a set figure or quota, although it was at one time when the Government "farmed out" the sealing privilege. Rather, the limit is now set by the number of seals of selected kinds which become available on the sealing beaches on certain days.

2. The wisdom of restricting the kill to males, and thus sparing the females, requires explanation. You are aware that wildlife managers often find it necessary to open the hunting season on female deer in

order to maintain a healthy balance of sexes. In the fur seal, however, polygamy is perhaps more highly developed than in any other mammal. The natural ratio of breeding males to females is about 1 to 26. Under the present system where young males are killed, the ratio approaches 1 to 50. Throughout the breeding season a large number of idle, adult males can be seen on the beaches. We conclude, therefore, that the harvest is being taken out of surplus stock and that the breeding potential is as high under management as it was in primitive times.

3. Through long experience in judging the age of seals, the men who do the killing are able to confine their take rather closely to three-year males. In 1948, for example, only 7 per cent of the take fell outside of this class.

4. The best season for harvesting the seal crop lies between the 15th of June and the 31st of July, a season of 47 days. In practice, the season is often extended as much as a week in either direction to compensate for natural variations in the time of arrival of the young seals. The season covers the period when the three-year class is dominant on the bachelor beaches and the fur is prime. Earlier, the older males are more abundant and later, toward August, two-year-olds and nomadic females swarm on to the beaches.

5. The importance of seal by-products is so far outweighed by the value of the skins that the utilization of waste materials has been slow in developing (Table 1). A reduction plant was built on St. Paul Island in 1918. There is yet no plant on St. George Island, where about 10,000 carcasses are left on the fields each summer. The by-products of the sealing industry are: (1) Oil, heat rendered, used in the manufacture of soap, as a basis for vitamin potent oils, etc., (2) oil, cold pressed, used in tanning fur seal skins, (3) meal, used in animal feed, (4) carcasses, smoked as winter food for Pribilof blue foxes, (5) carcasses, butchered as food for Government employees, and (6) trimmings from the genital region, sold to Orientals for medicinal use.

PROBLEMS IN CONSERVATION

1. *The optimum size of the harvest.*—How many seals can be killed each year without harming the breeding stock? Stated in another way: What percentage of the three-year class shall be spared? While a rough formula has been developed through experience it is still empirical. The present technique is to kill in such a way as to insure a ratio of about one idle bull to three breeding bulls. The ratio is measured during the annual bull count in the latter half of July. We hesitate to say that a practical answer can be reached through analysis of the known facts. It will be better, perhaps, to adopt a frankly experimental approach in managing the kill. For example, we will agree on a quota of 70,000 seals to be killed each summer and we will hold religiously to this quota for ten years. The consequences will then be studied. If the harvest holds up to the end of the ten-year plan and if the idle-to-breeding-bull ratio remains in balance, the conclusion will be that the original quota was right.

2. *Control of natural mortality.*—The causes of mortality are poorly known since most of them are effective while the seals are at sea. Losses are probably greatest when the young animals, at an age of

four months, leave the Pribilof Islands in November and venture into the stormy Pacific. From all evidence, they are abruptly weaned and are obliged to fend for themselves. Many of them are thought to be destroyed by killer whales (*Grampus rectipinna*). In the stomach of a whale stranded on the Pribilof Islands, 18 young fur seals were found, and in another 24. The death rate is apparently increasing among newborn seals from the ravages of the hookworm (*Uncinaria lucasi*). For example, in 1948 we counted on one of the breeding areas the bodies of 21,600 young seals, or 15 per cent of those born here this year. In 1922 the death rate was only 2 per cent. No serious attempt has been made by the Government to reduce natural mortality. A study should certainly be made of the hookworm.

3. *Fluctuations in the harvest from year to year.*—The take of skins from the Pribilof Islands was fairly predictable during the years when the herd was recovering from abuse, from 1911 to the early 1940's. That is, the take was steadily growing at a rate of 5 or 6 per cent. As the population approached a level the annual harvest began to rise and fall. This may be taken to mean that, as the seals grew crowded, they responded more readily to natural fluctuations in the environment. They became, as a population, more sensitive to the limiting factors of food, weather, predation, and disease.

Granted that a uniform harvest is desirable, the Government can approach the goal in a practical way by adjusting its killing methods to the behaviour of the bachelor seals. A proposal to abandon the three-year kill in favour of a combined kill of 3's and 4's is being considered. If adopted, a quota of four-year males will be taken in the early days of the season when these animals are dominant. A quota of three-year males will be taken concurrently and later.

4. *Improvement of fur quality.*—The main responsibility for improving the quality of the dressed and dyed seal skin rests with the Fouke Fur Company in its St. Louis factory. To a limited extent, however, the Government is able to co-operate in the field. We have mentioned the proposal to kill four-year-olds, which will shift the emphasis away from the 3's, especially the smaller 3's. The pelt of the small seal is difficult to process. It contains fine guard hairs which resist the ordinary operation of unhairing and remain as stiffer elements among the velvety fibres of the underfur.

The construction of new roads now makes it possible to drive the seals from the beaches to the killing fields with lessened effort. In recent years, the seals were often driven as far as a mile and some died enroute of overheating and exhaustion. Because of rapid physiological changes in the fur follicles, the skins from overheated animals required special handling which meant loss in efficiency. By shortening the killing season, also, the overheating and bruising of seals is reduced to a minimum. Study is being made of a plan to end the season by the 27th of July and still reap a satisfactory harvest.

An interesting thought with relation to fur quality is the effect of our killing methods on the evolution of the fur seal. We kill the earlier arriving three-year-olds and we spare the later ones to become the fathers of the future. Studies of branded, known-age animals have shown that the larger individuals arrive earlier than the smaller ones of the same year class. Are we not, then, reserving the inferior members as breeders, and if so, what can we do to correct the situation?

5. *Recovery of new by-products.*—The Pribilof Islands are a long haul from the markets of the world and as a result only the most valuable by-products of the seal industry can be salvaged at a profit. A study was recently made of the Vitamin A content of seal liver, as yet unexploited. In 197 livers analysed in 1948 the mean value of the Vitamin A was 0·25 dollars. One liver, though, was worth 4·25 dollars! Biologists are seeking a way to recognize and to segregate on the killing fields the more valuable livers.

Research Methods as Applied to the Seal Herd

1. *Counting seals.*—During the sealing season, an exact count is made of each animal killed (e.g., 70,142 in 1948). The plotted results show the daily and yearly fluctuation in the arrival of the bachelor seals.

In the latter half of July a count, accurate to within about 5 per cent, is made of the adult males (e.g., 16,163 in 1948). At the same time, the males are classified as breeding or idle. The count is made by a man on foot, implemented by walkways and towers.

A count of dead newborn young is occasionally made on selected breeding grounds near the 10th of August. Since the year 1922 it has been infeasible to cover all of the 21 breeding areas. During a sample count made in 1948, the biologists counted 21,600 carcasses on a strip of beach about a mile long. To avoid duplication in the tally, they marked each carcass with a pinch of white plaster.

Enumeration of seals on aerial photographs has been tried with poor success. Photographs taken in 1945 by the Navy and in 1948 by the Fish and Wildlife Service revealed fewer than half of the seals as individual animals. A Sonne strip camera will be used in the next experiment. Photographs have also been taken by the use of a camera suspended from a captive rubber balloon. So far, the results are inferior to those obtained by the use of aircraft.

2. *Measuring seals.*—One and one-half million seals have been killed since 1918 and of each, the length of the fresh body has been recorded. The goal is uniformity: to insure that the same size of animal is killed from one year to the next. A double check is provided by measurements taken later of the salted and the finished skins.

Measurements of experimental animals — branded or tagged seals of known age — are also preserved. As one of the results you may be interested to learn that the average bachelor seal is shorter than his ancestor of 33 years ago. This may mean that the modern seal is getting less to eat. The herd today is eight times its size 33 years ago and competition among its members for food is greater. Or the reduction in average size may mean, as we have implied, that the killing policy is at fault and we are putting evolution into reverse gear.

3. *Marking seals.*—Over 100,000 seals have been marked for one reason or another on the Pribilof Islands in the era of American ownership. The following devices have been used: hot-iron branding, shearing of fur, ear clipping, tagging, punching of flippers, and painting. A numbered tag made of monel metal or stainless steel attached to the fore flipper is the simplest and most useful device. About 50,000 such tags have been applied since 1941. Some are in good condition after seven years of wear on land and sea.

Seals are marked to provide specimens of known age for study of the size, fur quality, reproductive organs, dentition, and so on. Other marked seals are used in population studies, and still others as clues to the mortality rate.

4. *Watching seals on the breeding grounds and in captivity.*—Last summer a biologist visited twice daily a certain breeding ground where he watched three adult males in order to see how long they would hold their respective stations. One male stayed with his family for 59 days without food or drink. This illustrates what one may see on the fur seal islands, in addition to the phenomena of birth, death, courtship, and rearing of the young. Such observations give an understanding of the life of the species. And the wise conservationist tries to understand the normal picture so that, when abnormality creeps in, he will be alert to predict what effect it may have on the welfare of the population in his charge.

Observations of fur seals in captivity have produced information obtainable in no other way. Thus, it has been shown that the daily food requirement of a medium-sized seal is about 10 pounds. The only seals in captivity now are six in the Balboa Park Zoo, San Diego, California. On the 8th of August, 1948, one of them gave birth to a healthy youngster, the first ever born alive in captivity, after a gestation period of at least 374 days.

Many accounts have been written of the Alaska fur seal in terms biological, technological, legal, and romantic. In a few words we have tried to explain what the Fish and Wildlife Service is doing to conserve the species as an asset to the American people.

Discussion

Dr. Austin mentioned the excellent working of the Four Power Treaty in 1910 up to the time of its abrogation by Japan in 1921. He considered that the Japanese had a case for abrogation as the squid which was the principal food of the fur seal was also a most important source of food for the Japanese people. He said that a fur seal investigation programme had been started in Japan, under United States direction, but international co-operation was necessary for the investigation of the habits of fur seals.

In reply Dr. Cottam said that the U.S.S.R. had asked for an international conference on fur seals.

FLUCTUATIONS OF THE UNITED STATES BIG GAME POPULATIONS DURING THE LAST DECADE

By N. W. Hosley, United States Fish and Wildlife Service

Early History

In order to understand recent big-game conditions in the United States it is necessary to know some of the past history and the attitudes connected with them.

When the first settlers came to our shores and later reached the interior they found a great variety of big game in numbers which to them seemed inexhaustible. What these numbers actually were we can only guess. Some areas, such as the Great Plains, unquestionably numbered their game herds in hundreds of millions. Other areas, such as the virgin forests of the North-east, undoubtedly supported much smaller populations than is popularly supposed.

In contrast to the ownership of game in the Old World, the colonists decided that our game was to belong to everyone. This has become a law of the land although the landowner has the right to say who shall hunt on his holdings. Each state makes its own big game laws.

The early settlers were, of course, largely dependent on game for food and clothing and as early as 1646 the first closed season was put in force on deer in Rhode Island (Allen, 1930). The supply of big game was thought to be inexhaustible, however. The period of land clearing and agricluture saw most game eliminated in these areas. However, there was always good hunting in the uncleared lands ahead. Then came a time when the change from wild lands to cultivated or grazed ones had reached most of the better situations from coast to coast. The railroads had made the West accessible and the low point — in some cases almost extinction — had come for most of our big game species. Then, around the turn of the present century, the reaction began. From then on efforts have been made to rebuild the populations of the various species so far as present conditions will permit. In some cases this has been successful while in others it has failed.

WHITE-TAILED DEER (*Odocoileus virginianus*)

The white-tail originally was found over the whole eastern United States and extending to Texas, the Rockies and into the mountains of Oregon and Washington. It was missing or nearly so over much of the range during at least part of the 19th century. Then, due to the abandonment of considerable agricultural land, widespread timber cutting, long periods of protection, the establishment of refuges, laws allowing killing of only bucks, and restocking of vacant ranges, the deer came back. In 1937 the total population was estimated at 3,182,000 animals. In 1947 there were white-tailed deer in at least 44 states and the total estimate was slightly over 5,000,000.

This great increase has brought a real problem to many states. In most of them the hunters had been educated over a long period to kill only bucks. Now, with the herds in some states over-utilizing their food supply and dying by thousands, the public has to be taught that the necessary herd reduction is impossible without the removal of does. This change in thinking often takes years and, in the meantime, the deer go on starving. The states which have had least trouble with overpopulations have consistently killed both sexes.

MULE DEER (*Odocoileus hemionus*)

The mule or black-tailed deer is an animal of the more open, dry or mountainous country, It was originally found west of a line from western Minnesota, eastern Nebraska, central Kansas and western Texas to the coast in California and the western slopes of the Cascade Mountains in Washington and Oregon. Most of this range is still occupied.

Although the mule deer was not heavily hunted until long after the white-tail had been exterminated from much of its original range, it did reach a very low population in many areas. Buck laws, shorter seasons, and predator control have resulted in rapid increases in numbers. As an example, a state-wide open season in Utah in 1905 resulted in the killing of three deer. No hunting was allowed from 1906-1913 and then the seasons were limited for some time. The state reported a population of 200,000 and a kill of 60,000 in 1947.

The best known example of overpopulation is the Kaibab herd in Arizona. Here, on a refuge of 1,000 square miles established in 1906, there were an estimated 3,000 deer. The Indians had formerly killed many for hides and food. The combination of protection and mountain lion control, and control or reduction of grazing of domestic livestock, resulted in an estimate of 30,000 deer by 1924. The area supported over 150,000 cattle, sheep, and horses at that time. As a result of overpopulation the deer suffered a big die-off at this point. The herd has now built up to perhaps half of the peak population, but the forage has made only a limited comeback on the dry plateau.

In 1937 the U.S. population of mule deer was estimated at 1,271,000 and in 1946 the figure was 1,569,000.

Over most of the mule deer range, cattle and sheep graze the same ranges as the deer. Many cattlemen would like to see the big game numbers reduced, while the sportsmen would like to have more game and fewer head of live stock on the open ranges. The State Fish and Game Departments are caught in the crossfire and in some instances at least, the big-game figures are undoubtedly conservative.

COLUMBIAN BLACK-TAILED DEER (*Odocoileus hemionus columbianus*)

This deer is confined to the heavily timbered strip about 150 miles wide along the Pacific Coast from northern California to Alaska.

During the last two decades of the 19th century, thousands of these deer were killed for their hides. How many animals there were before this slaughter or at their low point of population is not known. Laws prohibiting the killing of does and fawns and the sale of venison were enacted and the herds came back rapidly. In 1937 there were estimated to be 232,000 in California, Oregon and Washington. By 1946 this had increased to 402,000.

ELK (*Cervus canadensis*)

This big deer with its tremendous antlers was found in colonial days over most of the northern and central states from eastern New England and the Appalachian Mountains to the western slopes of the Rockies. It occurred in all but six of the present 48 states. Probably in primitive days there were 7,000,000 elk in the United States. The venison is excellent, the animals range up to 1,000 pounds in weight (Anthony, 1928), the hides make excellent leather and for many years the tusks brought a good price since they were used as the emblem of a fraternal order. The animal is easy to kill and all these factors combined with a contraction of its winter range because of agricultural practices and livestock grazing resulted in almost complete extinction. The low point was apparently reached about 1895 but killing for tusks continued until the late 1920's. In 1910 only 60,000 were left in seven states (Jackson, 1944). Since then the elk has been reintroduced into many states. Refuges such as the one in Jackson Hole, Wyoming, have aided materially. In 1937 there were an estimated 165,000 animals and, in 1946, 193,300 in 24 states. The 1946 kill was estimated at 60,000.

WOODLAND CARIBOU (*Rangifer caribou*)

This northern animal was found in the United States only in a few places. In New England it was a rare straggler except in Maine. It was found on Isle Royale, Michigan, and across northern Wisconsin and Minnesota. In the Rockies, it was resident in western Montana. northern Idaho, and the north-eastern tip of Washington.

By 1937 there were thought to be 15 animals in Maine, three in Minnesota (nine additional ones were brought from Canada and released in 1938), and there were six in Washington. They had disappeared from Maine by 1946 as was probably the case in Minnesota. Only a few animals were known to occasionally migrate into Washington or Idaho.

MOOSE (*Alces americana*)

The largest American member of the deer family occurred originally across our northern forest from Maine to Minnesota and down the Rockies from the Canadian line into Idaho and Wyoming. There were probably never more than 250,000 moose in the United States and since the animal was easy to kill and greatly prized for venison, for skins, and as a trophy, it was soon decimated over much of our range. At present there is a good herd in Maine; there are a few stragglers in New Hampshire and Vermont; Isle Royale, Michigan has a good herd; there is a fair population in northern Minnesota and the western herds in Montana, Idaho and Wyoming are good sized. As a whole, though, the moose has been given complete protection from hunting in the north-east for twenty years with little change in numbers resulting. In Maine and Minnesota, at least, "moose disease" has resulted in the death of many animals. No particular disease organism has been agreed upon as the cause of the sickness. Many sick animals have been tick infested and one common theory has been that a virus was the cause of the trouble. Disease does not seem to have been important in the Isle Royale herd or in the Rocky Mountains.

In 1937 the total U.S. moose population was estimated at 13,300 and in 1946 at 18,700. About 550 were killed on the western ranges in 1946.

PRONG-HORNED ANTELOPE (*Antilocapra americana*)

The decline and rise of our antelope herds is one of the most striking stories in American game management. In the year 1800 the antelope were supposed to have been about as numerous as the bison, occupying 20 states west of the Mississippi. Reasonable estimates ranged from 30,000,000 to 40,000,000. The low point in the population was about 1908 when T. S. Palmer estimated 17,000 in the United States (Seton, 1929). As late as 1927 the species seemed headed for extinction when the National Association of Audubon Societies took over the Hapgood Brothers ranch "to preserve the remnant of prong-horned antelopes of the Nevada-Oregon region". This area, with later additions became the Sheldon National Antelope Range (Jackson, 1944). Other refuges, hunting restrictions, predator control and restocking of vacant ranges have decidedly changed the situation. By 1937 the estimated population was 131,500 and, by 1946, 173,600.

BIGHORN SHEEP (*Ovis canadensis*)

The range of these sheep at one time included most if not all of the mountains and buttes west of the 100th meridian except those near the Pacific Coast in Washington, Oregon and California. It has been exterminated in North Dakota and Nebraska, nearly eliminated in

Oregon and Washington, and killed out but reintroduced in South Dakota (Jackson, 1944).

Primitive numbers are very conjectured but may have reached 1,000,000 in the United States. The 1937 inventory was about 17,000 and by 1947 this had decreased to 14,000. Most of these were in federal refuges, National Forests and National Parks.

MOUNTAIN GOAT (*Oreamnos americanus*)

The history of this animal has run counter to that for the rest of our big-game species. It is found only in the most rugged mountains chiefly in Canada, but extending down into Washington, Idaho, Montana and South Dakota. The flesh is strongly flavoured so it has been hunted mainly as a trophy. It now occupies most of its ancestral range and its numbers have stayed relatively constant. The 1946 estimate was 15,700.

BISON (*Bison bison*)

This species is an example of what can happen to an easily killed, highly prized, plains animal under ruthless exploitation. Fifty million is considered a conservative estimate of the United States herd at the time of the earlier settlements. The great herds could be easily approached; the flesh was tasty and the skins became an item of·commerce for making "buffalo robes" used in carriages. By 1870 less than 6,000,000 were left on the plains. The low point in 1889 was estimated at 541 animals! Largely through the efforts of the American Bison Society and the establishment of federal refuges such as the National Bison Range in Montana, the Wichita Refuge in Oklahoma, Yellowstone National Park in Wyoming, and Wind Cave National Park in South Dakota, the herds have been built up to about 5,000 animals.

PECCARY OR JAVELINA (*Pecari angulatus*)

This wild pig once was found in droves through central and southern Texas, southern New Mexico and Arizona. The advent of settlers meant the decimation of the javelinas for they greatly relished cultivated crops. The flesh is palatable and the skins were used for leather. There are at present about 100,000 peccaries in the country and about 5,000 per year are killed.

BLACK BEAR (*Euarctos americanus*)

This most interesting and crafty animal originally occupied all of the United States except the deserts of the south-west, and occurred in every state of the Union. Although its flesh was not highly prized, the skins were used for rugs, coats, and the best ones at one time went to make caps for the Grenadier regiments of the British Army. Bears kill sheep and sometimes calves. They raid stored food, upset apiaries and eat fruits, so thousands were shot or trapped because of the damage they might do. At present most bears are killed for trophies.

At best, bear populations are difficult to estimate and those for primitive numbers are too vague to be useful. The animal reached its lowest numbers around 1900 and has been increasing ever since. This is largely due to giving it protection as a game animal in many States. Estimated at 81,000 in 1937, the total population had increased to 118,000 in 1941 and 142,000 in 1946.

GRIZZLY BEAR (*Ursus horribilis*)

This big bear originally inhabited the western two-thirds of the United States, coming east to the Great Plains. In the early days it fed on bison, deer, smaller animals and a great variety of other foods. Then came the settlers with their cattle and sheep. These furnished a much easier food supply and war was declared on the grizzly. While the numbers got down to an estimated 800 in 1921, they had increased to 1,100 in 1937, and 1,400 in 1946. These were mainly in National Forests and National Parks.

EXOTIC SPECIES

The European wild boar (*Sus scrofa*) has been introduced in at least five states—California, Kentucky, New Hampshire, North Carolina and Tennessee. It has apparently disappeared in Kentucky. It has been steadily increasing in the warmer states, reaching an estimated total of 2,200 in 1946.

The fallow deer (*Cervus dama*) is established in small numbers in Alabama, Kentucky and Nebraska. The estimated total was 187 animals in 1947. This small species seems to have little to recommend its use in our country. It inhabits the same type of cover as our native deer and is more of a grazer than the white-tail.

The European red deer (*Cervus elaphus*) has been introduced into Kentucky and has reached a total of about 228 animals. It has habits similar to our native white-tail so its introduction into white-tail cover is questionable.

On St. Vincent's Island, off the coast of Florida, the Sambar deer (*Rusa unicolor*) has been brought in. A small herd of about 50 animals has so far been confined to the island. Since it is much more of a grazing animal than our own deer of the region, it is hoped that it will be kept in this one location (Newman, 1948).

SUMMARY

If any generalization can be made of the trends of big-game numbers in the United States, it is that, with proper management, low populations of most species can be increased to and beyond the carrying capacity of the range. When sportsmen, and the interested public generally, become educated to the measures necessary for increasing the herds, it is difficult to prove that a saturation point can be reached and that numbers must then be reduced to save the range. A farmer knows how many cattle his pasture can support, but his thinking with regard to wild animals takes a very different course. Heavy shooting is, to most people, synonymous with declining populations. It is difficult to make them realize that, with overpopulated ranges, more shooting can mean more deer in the future. This problem of re-educating the public is the greatest one confronting our game managers today.

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MANAGEMENT OF MIGRATORY WATERFOWL (WITH SPECIAL REFERENCE TO GAME SPECIES)

By CLARENCE COTTAM and CECIL WILLIAMS, United States Fish and Wildlife Service

IN America the demand for game exceeds the available supply. Hunting and fishing are our most popular outdoor recreations. Expenditures made for hunting and fishing throughout this country amount to several times the total costs of all spectator sports combined. Directly and indirectly, Americans spend more than four billion dollars annually in the pursuit of hunting and fishing. Our two million duck and goose hunters spend more than 200 million dollars a year for their sport. Public interest in waterfowl is high because of the great economic, recreational, and aesthetic values of the resource.

NEED FOR MANAGEMENT

Undoubtedly, during the past few decades there has been a marked decline in American waterfowl populations. Though a number of circumstances have contributed to this downward trend, four factors have been largely responsible for the present status of this valuable resource. The need for management has become imperative as a result of the following conditions:

(1) *Encroachment of civilization,* involving agriculture, drainage, grazing, and other activities destructive of waterfowl habitat. Man and his agricultural and drainage programmes have been by far the most important factor in waterfowl reduction. At the turn of the century, some 3¼ million acres were under the plough in the southern Prairie Provinces, which have been regarded as the centre of continental waterfowl production. At the present time, some 47 million acres of this favoured nesting ground are under agricultural production and much of the remainder is subject to over-grazing. It is significant that in the United States there are now some 87 million acres of farm land in organized drainage districts and 45 million more in unorganized drainage enterprises. In the name of mosquito control, millions of acres have been "ditched" and thereby largely ruined for waterfowl habitat. Industrial or commercial development, intercoastal waterways, induced erosion, and the incursion of pest plants have largely destroyed innumerable marshes and ponds. With the advance of civilization, therefore, much of the original and essential waterfowl habitat, on both breeding and wintering grounds, has been irretrievably lost to waterfowl. Frankly, it is remarkable that a fair population of waterfowl is left on the continent.

(2) *Drought,* especially on the principal breeding grounds of our Prairie States and the Prairie Provinces of Canada. On the basis of some 125,000 banding returns, it is evident that the longevity of about 70 per cent of our waterfowl that reach the age of flight, is less than one year. Obviously, when drought or other catastrophe eliminates a large part of the production even for a year, the waterfowl population may easily go into a tailspin.

(3) *Disease and other mortality factors.* Every biologist knows that normal mortality is high in fecund species such as waterfowl. In addition to the normal mortality, lead poisoning has caused an appalling loss of birds, and oil and other pollutants have taken an enormous toll of our waterfowl populations. Botulism caused the death of at least one million birds in Salt Lake Valley of northern Utah alone in the fall of 1910 and again in 1913, and this disease, although under control on some managed areas, is still recurring on places throughout western United States and Canada. Fowl cholera and many other diseases also adversely affect the waterfowl populations every year.

(4) *Overshooting.* Though the loss from legal hunting may be less than the loss caused by most of the other factors listed here, a surprising harvest is taken each year. In the hunting season of 1946-47, sportsmen in the United States probably bagged some 19 million ducks and geese and lost another six million through crippling. During that same period perhaps four million waterfowl were bagged in Canada and possibly three-quarters of a million in Mexico. As evidence that the gun is no mean factor in the reduction of waterfowl populations, it may be noted that more than one goose of every five banded in Canada during the summer of 1947 was shot during the following hunting season. One out of five was reported to the Fish and Wildlife Service.

POLICY OF MANAGEMENT

Waterfowl management in America is based on the premise that all wildlife is the property of the people. As property of all of the people, wildlife must be held in trust for and managed in the best interest of all the people. This means that an individual cannot obtain an absolute property right in wildlife except under such conditions, restrictions, and limitations as may be prescribed by the legislatures of the States or by the Federal Government. An owner of land has a qualified interest in the game or other wildlife on his property, but this private interest is not one of absolute property right. Subject to regulations and restrictions imposed by the proper authorities, however, the owner of the land has the right to control the game on his land; thus, no other person has a right to go on this land to take the game without the land-owner's permission.

Through treaties or Acts of Congress, the Federal Government maintains primary or basic control over all species recognized by law as migratory. For these migratory game species, such as the Anatidae, Columbidae, and Rallidae, the Federal Government prescribes the conditions under which hunting or harvest of the crop, or control, may be effected. Within this framework established by the Federal Government, the states may impose additional restrictions or limitations.

Management of the non-migratory species is primarily the responsibility of the states. The Federal Government conducts some of the research essential for management of the non-migratory species, however, and frequently acts in an advisory capacity to the states and private interests.

NEED OF CO-OPERATION IN MANAGEMENT

In view of our conviction that this resource is the property of all our people, it becomes apparent that whatever affects waterfowl also affects all the people of our country directly or indirectly. Because of this, and because of the wide distribution and great mobility of the birds, management of our waterfowl is a highly complex problem. Migratory waterfowl are produced from the tundra marshes north of the Arctic Circle southward over much of the United States. The wintering range also varies with the different species of birds, but many of the game species go deep into Mexico and others continue as far south as northern South America. This continent-wide distribution calls for a continent-wide programme of management. If it is to be successful, the management of this resource must function as a unified, comprehensive programme. This will involve the close co-operation and co-ordination of the efforts and activities of all agencies and organizations concerned, including the Federal Government (through the Fish and Wildlife Service), the state game commissions, and private clubs, organizations, and individuals, as well as the interested foreign governments. To be truthful and realistic, the objective of complete co-ordination of the programme has not yet been achieved —either among our own citizens or with our neighbours—but considerable progress has already been made with respect to the states and the Federal Government and the Dominion and Provinces of Canada..

MANAGEMENT PROGRAMME

A comprehensive programme must be based largely upon four lines of activity: (1) Research, (2) Land and water management or habitat development, (3) Enforcement of laws and regulations, and (4) Dissemination of information, and good public relations.

Research

Management of this resource involves a multitude of problems; consequently, research in waterfowl management is extremely varied. Much of this work is being done by the Federal Government, but many of the states are now making valuable contributions, using funds available through the Federal Aid in Wildlife Restoration Act (known as the Pittman-Robertson programme).

An important problem of research is the development of technique and procedures in censusing waterfowl populations.

For about 14 years, an inventory has been taken during a five-day period in the month of January. The inventory is made with a great deal of volunteer help working under the direction of our game-management agents. This project is designed to secure comparative data on trends in the waterfowl population at the close of the hunting season, when the birds have become more or less stabilized and concentrated on their wintering grounds. This inventory provides at least a rough picture of the probable nesting trends.

Extensive efforts also have been directed toward appraisal of waterfowl breeding populations and conditions. Our own work is now well co-ordinated with that of the Dominion and Provincial Governments of Canada, and many of our states co-operate in unified breeding and wintering survey programmes. Until more facilities become available and permit more sampling of isolated areas of the Far North, we shall not attempt to estimate total breeding populations or total production, but rather shall rely on the sampling, which will provide satisfactory trends.

Before 1946, the Fish and Wildlife Service obtained its appraisals of breeding-ground conditions in the northern states, Canada, and Alaska, by having its observers make broad, general surveys of breeding territory. These surveys or samplings, which covered about the same areas at about the same seasons each year, gave good qualitative information. To obtain quantitative data which would permit sounder comparisons from one year to the next regardless of the observer, the Service biologists have recently initiated a more standardized and scientific system of measuring population and production trends. While appraising conditions and breeding populations in the principal breeding grounds of our North Central States and the Prairie Provinces, researchers have used airplanes, automobiles, and boats. Randomized transects (usually ¼ mile wide) have been covered to obtain information regarding the number of potholes, sloughs, and lakes per square mile of transect or land type; the per cent of the available water occupied by breeding birds; and the average number of breeding pairs per area, per transect, and per square mile of land type or area sampled.

Extensive banding operations have already provided valuable data for management of waterfowl. More such work is necessary to determine the limits of flyways as used by various species, degree and extent of movement, degree of overlapping of flyways, differential sex and age migrations, longevity, survival rates of different species, and sexes in the different flyways. This information is essential as a basis for wise regulations. These data are also essential to the accurate appraisal of new habitat development on both nesting and wintering grounds.

Successful administration of our wildlife resources must also include research on mortality factors. Effective management must take into consideration the causes and extent of loss from various factors, must put into operation the most desirable means of controlling or minimizing losses. Though the findings are not yet conclusive, studies of botulism unquestionably have enabled game managers and sportsmen to save many hundreds of thousands of birds. The toll taken annually by botulism, fowl cholera, and many other diseases, as well as by certain parasites, makes it imperative that research along these lines be continued.

It is unfortunate that one of the more serious unsolved problems is too little appreciated. Research must find an effective substitute for lead, as apparently the present losses from lead poisoning can be prevented only by development of a pellet that has proper ballistic qualities and yet will not prove injurious when ingested by birds as food or gravel.

Other research is directed toward determining ecological requirements and relationships of the different species, as well as the characteristics of the ideal nesting, brooding, feeding, and wintering grounds of waterfowl. Such information furnishes the background necessary for the development of the extensive and effective Federal refuge programme.

Land Management and Habitat Development

The objective of this programme is to establish, restore, and maintain highly attractive waterfowl habitat, including marsh and shallow lakes in strategic waterfowl concentration areas, on the nesting grounds, on the principal migratory flight lanes, and on the wintering grounds.

At present, the Federal refuge system comprises some 200 waterfowl refuges aggregating about 3½ million acres. Direct appropriations of Congress and the revenue from the sale of the Federal "dollar duck stamp" (a requirement of all waterfowl hunters more than 16 years of age) support this Federal refuge programme.

We may well regard this refuge programme as a great national insurance policy to secure the perpetuation of at least the essential minimum breeding population of waterfowl. This system of refuges safeguards a portion of the hunted population and, to a large extent, provides protection against complete losses from drought. Our people also receive many indirect values from the programme, as the same conditions that favour wildlife and its habitat tend to raise water-level tables, provide flood control, prevent soil erosion, and preserve the fertile soil.

Some of the Federal refuges are designed primarily as breeding areas; others are used largely as temporary feeding and resting grounds during migration; and still others serve principally as wintering grounds for migratory birds. Development of these areas has greatly improved nesting opportunities and has materially enlarged the available wintering habitat. Most of these refuges are by law inviolate sanctuaries; even on those refuges on which a limited amount of shooting is permitted, there are extensive sanctuary areas. It is hoped that ultimately some kind of refuge may be established approximately every 200 or 300 miles on the flyways, as this arrangement could be expected to insure protection to at least the minimum required breeding population. It is not expected that these refuges will be adequate in themselves, but that they will be supplemented by natural areas and refuges under state or private jurisdiction. The Federal refuges serve as public demonstration areas, and state and private interests are encouraged to set aside, develop, and manage similar marsh areas. During the past year or two, most of the states, using their Federal Aid grants, have greatly expanded their waterfowl-management and refuge-development programmes. These states have already acquired more than 115,000 acres which are managed primarily as waterfowl nesting, resting, or feeding areas. Portion of some of these areas are open to public hunting on a managed basis, although a suitable portion of each is maintained as a sanctuary.

Effective and economical marsh development must take into consideration the local needs and physiographic conditions. The Fish and Wildlife Service is making every effort to obtain multiple use of each refuge, to supply a wide variety of habitat—suitable nesting, resting, feeding, and moulting areas—for all the fauna that might use a particular refuge. The requirements of the various species differ considerably, especially in the relationship and position of the areas or units of habitat for nesting, resting, feeding, and moulting. The "tippers" or shoal-water species require shallow water and a varied "cut-up" marsh; the divers demand more open water. Under these circumstances, habitat development requires an extensive programme of diking and impoundment, as well as provision for the control of water levels.

In connection with the refuge programme, it is important that the gigantic "River Basin" and other proposed development programmes give proper consideration to the welfare of waterfowl.

Enforcement of Laws and Regulations

The primary purpose of regulations cannot be over-emphasized. The primary purpose is to make certain that the kill or harvest of game does not exceed the annual increment of increase—in other words, to prevent the kill, plus other mortality factors, from causing a decline. The intent of those who formulate the regulations is not to see that each hunter obtains his limit each day he goes afield, but rather to insure the perpetuation of this great resource. It is because of this objective that severe restrictions must sometimes be placed in the regulations.

The secondary objective of the regulations is to make available to all the people in all the sections of the country an equitable share in the harvestable crop. As a step towards the equitable distribution of the harvestable crop, flyway management has been instituted.

Based upon flyway management, the regulations pertaining to bag limits and to time and length of season, are not likely ever to be uniform in all sections of the country. They were not during the past season. On the basis of the expected waterfowl population and the hunting pressure within a particular flyway, the length of season and the bag limit were determined for each of the four flyways in the United States. The hunting regulations permitted a season of 30 days in each state in the Atlantic and the Mississippi Flyways, 35 days for each state in the Central Flyway, and 40 days for each state in the Pacific Flyway. Hunters in the Atlantic and Mississippi Flyways were authorized to take four birds per day and to have eight in possession after the first day, while limits of five birds per day and ten in possession were authorized in the Central and Pacific Flyways. Because of the short season that could be authorized for hunting, and because of the desirability of causing that hunting to be distributed as equitably as possible for all sections of any state having varied physiographical features, each state game department was permitted to select its own seasons within broad limitations set by the Fish and Wildlife Service. States could choose a continuous season or, if they preferred, might select a split season with the loss of a few days to compensate for the advantages gained; thus, those states with a 30-day season could choose either this continuous season or two periods of 12 days each; the states granted a 35- or 40-day season could substitute two periods of 14 or 17 days each, respectively. It was arranged that the season could start at the discretion of the state on October 8, October 15, or any second week thereafter following the 15th of October (i.e., October 15, October 29, November 5, November 19, etc.); but all hunting for migratory waterfowl had to cease not later than January 8. On the opening days, hunting could not start before 12 o'clock noon; on all other days, it could start 30 minutes before sunrise; each day the hunting had to stop not later than one hour before sundown. It was fully recognized that these regulations were restrictive. The regulations were designed with the idea of providing an improved breeding stock for the following nesting season.

Enforcement of regulations is essential to the administration and management of our waterfowl resource. Only by means of enforcement of regulations can a crop be harvested satisfactorily and the necessary breeding stock be given protection. At present, the Fish and Wildlife Service has only 83 law-enforcement men (including five supervisors, two pilots, and one biologist) in the United States, while the work in Alaska is carried on by 17 members of the staff (including four pilots, one supervisor, and one assistant supervisor), and 20 Deputy Alaska Game Wardens who receive no compensation. These men work in close co-operation with state officials concerned with enforcement problems.

Dissemination of Information; Good Public Relations

The encroachment of civilization on waterfowl continues apace. Somewhere along the line it must be delayed to permit the adjustment of the resource into the future pattern, or the people will have to be satisfied with a life comparatively barren of values derived from the birds. Research on waterfowl and efficient management will continue to do much toward preserving these values, but well-informed public opinion is also needed to support research and management and to demand intelligent legislation and adherence to regulations.

Public opinion has an inherent potency to do either harm or good. To be constructive rather than destructive, public opinion must be well informed; it cannot be well informed unless it is based on the factual information available. This presents an important responsibility to the various agencies administering the waterfowl resource. It also places a moral obligation upon individuals who write about waterfowl or their problems.

The Fish and Wildlife Service has sought to bring to the people in a comprehensive manner, the accumulated and current facts bearing upon waterfowl, as well as the common-sense interpretations of those facts. Information available to the Service has always been available to anyone who was interested, and every year the Service gives replies to thousands of questions. In addition, the Service has brought available waterfowl facts to the attention of the public through articles in technical and popular magazines, books, published reports and reviews, press releases, movie films, talks, and radio programmes. Well-advertised public meetings held in the spring in different sections of the country have also been effective in informing our people of current waterfowl conditions and problems. With all this, much publicity work remains to be done if the public, as owner of the resource, is to get the factual answers it and the waterfowl resource deserve.

The Federal waterfowl programme is also being brought closer to the public through correlation with programmes of the various states. This has been made possible in recent years by Federal Aid grants from taxes on arms and ammunition. Through such co-operative effort, sportsmen of the different states have become more aware of where their birds are produced, their migration routes, the factors affecting them adversely or working to their benefit, and other important problems of management. This is a long step forward towards preserving the values of waterfowl for future generations.

The waterfowl programmes of the Fish and Wildlife Service and the State game departments are being correlated as closely as possible with those of Canada. The various programmes are gradually developing into a unified international programme. Biologists and administrators of the United States and the Dominion of Canada have long worked together, attempting to learn facts and work out measures advantageous to the waterfowl and to the people of both countries. The breeding-ground investigations of this past year stand as an excellent example of how a unified waterfowl programme is developing. The Fish and Wildlife Service sent aircraft, automobiles, airboats, and its crew to Canada to work with Canadians in appraising waterfowl breeding conditions and in banding waterfowl populations. The Dominion Wildlife Service and various Provincial game branches supplied additional equipment and manpower to make up the necessary aerial and ground crews.

The Wildlife Management Institute conducted other breeding-ground studies in Manitoba and in eastern Canada. In the United States, Minnesota, Wisconsin, Michigan, North Dakota, South Dakota, and Nebraska entered into the breeding-ground programme, using methods similar to those applied by investigators in Canada. Other states also carried on breeding-ground studies, using other methods but contributing greatly to the over-all knowledge of breeding waterfowl for the season. The joint efforts of all agencies during the nesting season are culminating in the joint preparation of a detailed report, “Waterfowl Breeding Populations and Conditions, 1948”, which is soon to be released to the public. This marks the trend in public relations and co-operative investigations—a healthy trend—which undoubtedly will expand appreciably in the years to come.

To be effective, waterfowl programmes for the continent must likewise include the wintering areas south of the United States. The treaty with Mexico represents the first step in this direction. Others include surveys of wintering conditions in Mexico, Guatemala, Cuba, Haiti, the Dominican Republic, and Puerto Rico. Excellent treatment has always been extended to our biologists assigned to studies in these countries, and there is every indication that the same close co-operation that prevails between Canada and the United States may be anticipated from our southern neighbours.

SUMMARY

Our waterfowl are a valuable resource, a renewable resource of great interest to a growing number of people. As the property of all the people, American migratory waterfowl are being managed in the United States by the Federal Government (through the Fish and Wildlife Service) for the continued benefit of all the people. Following the birds from nesting grounds as far north as the Arctic Circle to the wintering grounds in South America, we are seeking to achieve a comprehensive, continent-wide programme of management. Research, land management and habitat development, enforcement of laws and regulations, and widespread understanding and co-operation, are paramount factors in the success of such a programme.

THE FEDERAL PROGRAMME WITH RELATION TO THE FUTURE DEVELOPMENT OF PACIFIC FISHERIES

By Milner B. Schaefer, Pacific Oceanic Fishery Investigations, United States Fish and Wildlife Service, Honolulu, T. H.

One hears a good deal these days about the increasing inability of the land to produce sufficient food, particularly proteins, to supply the needs of the world's growing population. It has been suggested that a more intensive harvesting of the sea is a partial solution to the problem. Indeed, some highly populated maritime countries, such as Japan, normally obtain a good share of their protein from marine sources. An increased production of fish from the sea might be obtained by increased yields from the major fisheries now under exploitation, either by increased intensity of fishing or by expansion of fishing grounds, or by utilization of species now little used or unused.

Factors Controlling the Growth of Commercial Fisheries

Before we examine the present condition of some of the American Pacific fisheries and the outlook for increased production in the immediate future, it is pertinent to consider briefly how fisheries develop and what factors limit their growth.

A fishery, when it begins, operates on a virgin stock of fish and very high yields per boat or per man are obtained. The stock is at first exploited throughout only a part of its range and the boats fish quite near to the point where the fish are canned, frozen, or otherwise processed or marketed. The total catch, of course, is small because only a few boats and men are engaged in the industry. If the fishing proves profitable, more men are attracted to the new enterprise and the total catch increases, but the catch per boat goes down because the standing crop of fish is inevitably reduced by the harvesting. Too, boats must take in more territory to make their catches, and trips at sea are longer.

However, experience enables the fishermen to improve their gear and methods, partly offsetting for a time at least, the decreased yield per boat resulting from the decrease in the fish stock and the longer distances which must be covered. Thus, as the fishery grows, more gear is employed, and improved gear, and more area is covered, but all the while the standing crop, the total stock, is decreasing because of the increased mortality rate due to fishing, and the economic return per man is dropping. So long as the return to the fisherman is, however, greater than that of any other fishery in which the boats and men might engage, more fishermen (by "fishermen" we include boat-owners) will be attracted so that the fishing tends to keep growing until the economic return falls to a level equivalent to that of other fisheries in which the men or boats might alternatively engage.

It is important to note that the point at which the economic return per unit of effort becomes insufficient to permit further increase in intensity is dependent only on price and catch per unit of effort and not on total production. The maximum return per unit of effort is generally obtained from the fishery in its early stages of growth when the total annual catch is small. As the fishery grows in range and intensity, the total catch increases, but the catch per unit of effort decreases. Eventually the balance point is reached where the size of stock and intensity are such that a maximum total annual yield is possible, but if at that point the catch per unit of effort is such as to make further expansion profitable, the intensity of the fishery will still continue to grow, and both the total annual catch and the catch per unit of effort fall off. This stage is often termed "overfishing". Fisheries, such as that for soupfin shark, where the dollar value of the product is very great, may be fished profitably at a level of standing crop far below that at which the maximum annual total yield might be obtained. Since the economic return per unit of effort is the controlling factor on the intensity of the fishery, it may stop growing before, at, or after the point of maximum possible yield is reached.

The above is rather simplified, of course. Since the economic return depends on the catch per unit of effort expended, the dollar price per pound of product, and the purchasing value of the dollar, and since the several fisheries in which a boat or man might alternatively engage are subject to continuous variation in the size of the standing crops of the fish on which they are based, both as a result of fishing and of natural fluctuations in the conditions on the sea, the level of intensity at which the fishery may be profitably pursued is constantly shifting for any given fishery.

The regulations of conservation agencies also modifies the situation. The various governmental agencies charged with conservation of the resource attempt to impose conditions under which the standing crop will not be reduced below the level at which the maximum annual total catch may be obtained. Such regulations may take the form of restricting the amount of time during which the fishing may be pursued, restricting the types of gear which may be employed, restricting the area which may be fished, or restricting the part of the stock to which the fishing effort may be applied; all of these tend to have the effect of decreasing the level of fishing intensity at which it is profitable to fish and thus curtailing the increase in fishing intensity. A more direct approach is that employed in the halibut fishery and some others of putting a ceiling on the amount of fish which may be captured in a year.

STATUS OF SOME PACIFIC FISHERIES

With these concepts in mind, we may examine the present status of some of the great American fisheries in the Pacific on which the Federal Government is conducting research, and perhaps see what possibilities exist for new developments.

The halibut fishery has been the object of intensive study for over twenty years by the International Fisheries Commission. It has been pretty well established that the intensive fishing of the 1920's reduced the stocks of all grounds to a point below that at which the maximum annual yield might be obtained. Through careful regulation of the total catch, the Commission has permitted the stock to be built up gradually, and although no great increase in total catch has yet resulted, the catch per unit of effort has been remarkably increased. Through continued careful regulation of this fishery further improvements in total annual yield may be expected, but certainly no spectacular expansion of this fishery, which now exploits the species through most of its range, can be expected. The Bering Sea region, which alone of the species' range has not been much fished, appears from the results of recent exploratory operations there to offer little possibility of much production.

The Pacific salmon fisheries, yielding some 600 million pounds of fish per year, are dependent on a multitude of separate populations of five species, and these species are fully exploited throughout their range. Since these fishes return to their home streams to spawn, and are fished primarily as they approach these streams on the return migration, the different stocks may be exploited rather unevenly, depending on the economic circumstances in each case, and on the effects of the fishing regulations imposed by the various governmental conservation agencies. In almost, if not absolutely every stream from California to Bristol Bay, however, the yield of salmon has decreased from its earlier levels, either as a result of the fishing intensity, the encroachment of civilization on the streams, or both. The yields of the salmon fisheries may be increased by the application of the results of research to the regulation and management of the fisheries, but here again we are dealing with a case where the fishery has passed beyond the level of optimum total yield. The five species are exploited throughout their range and further development must be by means of better management of the fishery. In Alaska the Fish and Wildlife Service is the responsible regulating agency. Here the Service not only conducts research into the ecology of the salmon and on the relationship of the fishery to the stocks and yield, but also makes regulations applying the results to the fishery and hopes to undertake stream improvement activities for the purpose of increasing the success of spawning and thus increasing the stocks.

The Pacific herring fisheries, like herring fisheries the world over, are subject to large fluctuations little related to the amount of fishing, resulting from large variations in the survival of young fish from the spawnings of different years. By keeping track of the variations in year-class strength and regulating the amount of catch accordingly, the Fish and Wildlife Service in Alaska maintains the yield of herring at a somewhat more nearly constant level than would perhaps obtain under an unregulated fishery. Whether this results in any increase in average total annual yield is a moot question, but it at least tends to level off some of the violent fluctuations and assists in stabilizing the industry. In any event, the Pacific herring fisheries seem to be rather fully exploited and the problems are problems of management rather than of development. No large increases in the average annual yield of the herring fisheries may be expected.

The fishery for the pilchard, also called the California sardine, extends from lower California to British Columbia, or over the entire range of occurrence of the species in worthwhile quantities. The total annual yield during the decade 1934 to 1944 averaged over 500,000 tons. Since 1945 the yield has declined drastically as a result of a series of poor incoming year classes, related partly at least to unfavourable conditions in the oceanic environment. We need not examine here, however, into the causes of this decline. Suffice to say that the intensity of the fishery is such, and has been such for the past decade, that, together with the natural death rate, the total mortality each year is of the magnitude of 70 per cent. Obviously, no important expansion of this fishery may be expected. The level of intensity corresponding to maximum sustained yield has probably been approached and perhaps exceeded. Extensive investigations into the ecology and population dynamics of the Pacific pilchard population are being conducted co-operatively by the three Pacific Coast States, the Province of British

Columbia, Scripps Institution of Oceanography, and the U.S. Fish and Wildlife Service, in order to reach an understanding of the factors controlling the abundance of the fish and their behaviour, including the effect of the intensity of fishery. An understanding of the mechanisms involved may lead to management plans which will result in greater yields in the event that the intensity of fishery turns out to be a significant factor in determining the amount of recruitment, and should, in any event, furnish a basis of predicting abundance which will be of considerable economic value to the industry.

These fisheries—halibut, salmon, herring, pilchards—have reached full maturity. They extend over all or nearly all of the range of the species involved, the stocks are fully exploited. The intensity of fishing effort has nearly reached, reached, or passed the point at which the maximum sustained yield may be obtained. Such fisheries can be improved only by careful management. Further geographical extension, improvement of efficiency of fishing techniques, or increase in number of men and boats engaged in fishing, cannot be expected to increase the total yield. Such is not true of all the fisheries, however. The trawl fisheries, for example, which exploit the bottom fishes—flounders, rockfish, and cods—of the continental shelf, have increased tremendously in the last two decades, but have certainly not reached the full development of which they are capable. These fisheries off the coasts of the Pacific Coast States and British Columbia expanded their production from 10 million pounds in 1934 to over 25 million in 1941, largely as a result of the increased demand for fillets of fresh fish. With the advent of World War II and the heavy demand for fish as a meat substitute and for army rations, the production of these fisheries shot up to over 70 million pounds. This production was obtained, however, from only a part of the trawling grounds available to the Pacific fishermen. The grounds of the Gulf of Alaska and the Bering Sea remained untouched, although exploratory operations of the Fish and Wildlife Service before the war indicate that there are considerable populations of the commercially valuable bottom fishes in these waters. Since the termination of hostilities, with the resulting decrease in demand for the products of the trawl fisheries, the intensity of fishing, and consequently production, has declined from the wartime high. This fishery has, obviously, not reached its full possible development. The Fish and Wildlife Service has this year commenced exploratory fishing operations in the Bering Sea and Gulf of Alaska which are expected to yield more precise data on the bottom fish stocks available there and which may serve as an aid to the development of these fisheries.

Among the little exploited bottom fisheries may be included that for the King crab in the Bering Sea. While this species was not, prewar, fished by our fishermen, the Japanese based a mothership fishery on the King crab stocks of the eastern side of the Bering Sea. Concentrations of crabs here were never as great as those of the Kamchatka area, but were sufficient to support up to four motherships and associated catching boats, as many as 8,600,000 crabs being taken in one season (1940). The Fish and Wildlife Service conducted limited exploratory fishing in the Bering Sea just before the war and on the basis of that experience several small crab fishing enterprises have been started in the last three years. This past summer a mothership, financed by the Federal Government, made a crab fishing trip to the

Bering Sea and took and processed some 400,000 crabs. Here may be the basis for the development of a new American fishery.

Among the fish products in strongest demand in United States markets is canned tuna. To satisfy this demand the Pacific American tuna fishery last year caught nearly 250 million pounds of tuna fish from which over five million cases of canned fish were packed, an all time high for the industry. This production was, however, achieved by greatly increased intensity of fishing and extension of fishery range. The demand continues high and there is constant pressure on the fishery to grow, to expand to yet newer grounds. That such growth is possible seems very likely, particularly for the albacore and for the tropical and subtropical tunas, the yellowfin and skipjack.

The fishery for albacore is conducted in the eastern Pacific only along the fringe of the ocean from British Columbia to Mexico, using only surface fishing gear during the short summer and fall season when the fish approach these shores. On the western side of the same ocean, on the other hand, the Japanese have developed, in addition to similar inshore fisheries, offshore fisheries at distances up to 2,000 miles from their shores, catching the fish at considerable depths. The probability of the possible development of an analogous fishery in the eastern Pacific seems rather high.

While we think there are albacore to be caught in new areas, we know that there are skipjack and yellowfin to be taken in new areas open to our fishermen. The fact that considerable quantities of these species exist in the tropical and subtropical central and eastern Pacific is attested by the production of the Japanese fisheries in their former mandated regions (now the Pacific Trust Territories), by the fishery in the Hawaiian Islands, and by the observations of Fish and Wildlife Service scientists in these regions and in the Line Islands as well. That the fish are there, there can be no doubt. The catching of them, however, is a bit of a problem and requires something more than a simple extension of the present mainland tuna fishing methods. In the first place, a good share of the yellowfin tuna occur in the depths of the sea and are not to be taken by the familiar methods which rely on surface fishing, but must be caught by the submerged long line as used in Hawaii and elsewhere, or perhaps by some totally new kind of gear. Again, the skipjack of these regions seem to behave, to move and feed and sound, rather differently than those to which the mainland fisherman is used. The live bait available, as well as being scarce, is of different type and must be differently caught and handled than that used on the mainland. In order to foster and assist the development of these mid-Pacific fisheries, and in order to provide the scientific basis on which they may be properly managed when management becomes necessary, the Fish and Wildlife Service, under authority of recent legislation, is now preparing to undertake rather extensive studies of the tunas of this region, their life histories, ecology and distribution, methods of catching and handling, supplies of bait available and data necessary for management thereof, and similar problems. To this end we are outfitting three research vessels which will put to sea in the summer of 1949 from Honolulu, where they will base. It is hoped that the studies completed by the scientists aboard these vessels will be of the greatest value both to American fishermen and those of all the Pacific Nations in developing new and enlarged high seas fisheries for tunas and other kinds of pelagic fishes.

SCIENTIFIC SOIL CONSERVATION

By H. H. Bennett, Soil Conservation Service, United States Department of Agriculture

During the past two decades a new science—the science of soil conservation—has been in process of development. And this development marks the beginning of a new era in agriculture—the era of soil conservation farming.

This new kind of farming, for the first time in history, finds conservation of land, water, grass, forest, cultivated crops, and wildlife intimately tied together and co-ordinated on the basis of land capability and need. This is a basic tenet of modern soil conservation. It is nature's method, which man too long failed to understand, or ignored. Sound agriculture, profitable industry, thriving municipalities, healthy commerce, and the vigour and welfare of all the people depend in a large measure on this scientific, lasting conservation of our basic life-giving resources of land and water.

Need for Conservation of Soil and Water

Throughout the world there is pressing need for better adjustment of agriculture to its physical environment—better use of land and water which makes it productive—not only to gain a sorely needed increase in per-acre production but also to maintain a healthy agricultural economy, which could be disastrously undermined through continuing impairment, or ruin, of our limited supply of productive land. Such essential changes call for the elimination of land-use practices haphazardly and wastefully applied to the land, and for the widespread adoption, in their place, of various conservation measures scientifically fitted to the needs and physical characteristics of the land, the climate, and the type of farming.

These practices, applied in this way, will at once protect the land and increase its productivity by conserving the soil itself—the whole soil—its available elements of fertility and all that man and nature put into the soil, along with a valuable portion of the rainfall that otherwise would be lost as runoff. This is of primary importance, because there is no other way by which the agricultural plant of the world can be kept in a safe and permanently healthful condition necessary to support a permanent agriculture. It likewise is the only way to get from the land anything like the sustained yields necessary to feed the world.

Scientific Soil Methodology

Soil conservation as practiced by trained soil conservationists is a new technique in land use and protection. This modern technique of safeguarding the land is not only the most economical and effective way of protecting farm land from destructive erosion and other impoverishing effects of improper land use, but it is the only practical way to keep cultivated and grazing land permanently productive. Other methods, such as the old single-practice method of terracing, have failed to the extent of permitting millions of acres to be ruined for any further practicable cultivation within any reasonable future time. Land riddled with gullies, too deep to cross with farm machinery, has no further value for cultivated crops. The same is true where rock is exposed or lies within plough depth.

Modern soil conservation is the treatment of land with those measures that keep it permanently productive while in use. Such treatment calls for the use of a variety of measures and structures designed to fit the different needs and adaptations of the various kinds of land, used for different crops under different climatic conditions. The soil and water conservation techniques thus scientifically employed have been developed through painstaking research and through the accumulated experience of agriculture. This methodology involves three basic steps:

1. Detailed conservation surveys to determine the kind and condition of the land: its capability to produce;

2. Acre-by-acre conservation farm planning, to guide land treatment and use;

3. Treatment and use of the land with needed adaptable measures, to prevent soil erosion and water waste, preserve fertility, and assure permanent productiveness.

CONSERVATION TOOLS USED

In order to apply a complete programme of conservation-farming methods to a farm, in its entirety, it is necessary to combine the techniques of all the pertinent branches of agricultural science, along with the necessary engineering, hydrologic, biologic, geologic, chemical, and other skills. A single farm thus may require contributions from soil and water conservationists, agronomists, foresters, engineers, hydrologists, biologists, geologists, chemists, and others. Take away any one of these techniques or technicians, and you thereby weaken the whole conservation approach.

All measures that help keep land in condition favourable to sustained production are tools of conservation: Terraces, contouring, organic matter, grass, legumes, shrubs, trees, crop rotations, changing the use of land, rotation grazing and pasturing limited to the carrying capacity of the range, stockwater ponds, fertilizer, lime, drainage where the land is too wet and irrigation where it is too dry—all of these and whatever else is needed are conservation tools that are required to get soil conservation done properly. These tools are used singly where it is easy to safeguard the land, and in combination, one supplementing another, where the conservation needs are more complex.

That is why, in the United States, we build our national soil conservation programme, and every individual landholder's soil conservation programme, on the solid foundation of land capability surveys. Parcels of land differ—often within the boundaries of a single field—just as people differ in their characteristics and their ability to do things. These individual capacities of the different kinds of land must be determined before a particular piece of land can be made to produce safely and most efficiently. It is important, therefore, in soil conservation to know the principal land facts over a farm or a watershed. It is necessary to know what the soil is; the slope of the land—its degree and direction; and the condition of the land as the result of the way the land has been used. For flood control operations, these and other typical facts must be known for entire watersheds, such as infiltration rates, underlying conditions with respect to drainage, and seasonal runoff characteristics.

BASIC CONSERVATION SURVEYS

The conservation survey formula worked out by the Soil Conservation Service, and now in use throughout the United States, recognizes eight land capability classes, according to soil, slope, amount of erosion, susceptibility to erosion, and other land conditions.[1]

Our land capability Classes I, II, and III are the better, least sloping and least erodible lands. Such lands are suitable for continuous cultivation with proper safeguards and treatment. Progressively more protection is needed for the higher-numbered classes. Class IV land is the critical, intermediate type of land which, because of susceptibility to erosion or other hazards, should be used principally for hay and pasture—although some of it may be cultivated occasionally—usually not more than one year out of six—under proper conservation safeguards. Classes V, VI, and VII are lands that are not suited to cultivation under any circumstance. They are suitable only for some kind of continuous vegetative cover, as grass or trees, with progressively more protection for the higher-numbered classes. Class VIII takes in such areas as rocky highlands, marshes, and dunes—that is, land which is valuable only for wildlife or recreational purposes.

THE COMPLETE CONSERVATION FARM PLAN

In the United States, when a land capability map has been made of a farm, the Soil Conservation Service technician and the farmer go over the fields, pastures, and woodlands together and work out, co-operatively, a complete, detailed conservation plan of the entire farm. This plan shows, field by field, the conservation treatment and management needed, year by year, along with necessary adjustments for the operator's economic, market, and other conditions. It is a blueprint for the safe and economical use of the land, showing not only where structures, such as terraces and farm ponds, are needed, but where row crops should be grown, what land should be put into grass or trees, and a schedule for crop rotation, conservation pasture or woodland management, and so on. Moreover, the plan calls for using in a given field those measures, where possible, that benefit adjoining fields or adjoining farms. Structures and cropping measures are all scientifically co-ordinated so as to provide maximum effectiveness through the principle of mutual support and appropriate application to the land.

CONSERVATION LAND TREATMENT AND MAINTENANCE

Such a plan, of course, cannot ordinarily be put into full effect at once, or even in a single season, although some of the spectacular and highly successful conservation "remaking-a-farm-in-a-day" and "farm facelifting" events you may have heard about might indicate that it could. But careful conservation survey and farm planning precedes these one-day events.

Ordinarily, a farmer is likely to need several seasons in which to complete such items of work, for example, as terracing, installation of irrigation or drainage systems, and realignment of fields, roads, and fences to fit the contour as nearly as possible. He must have several years to complete his first round of conservation crop rotation, seed and improve his pastures, or establish rotation grazing on range land.

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[1] Hockensmith, R. D., The Scientific Basis for Conservation Farming, *Jour. Soil and Water Cons.* 2 (1): 9-16, January, 1947.

He does all these things, and pays for them, the Soil Conservation Service furnishing technical assistance without charge, through the farmers' soil conservation districts, at the farmers' request. Thereafter, maintenance of soil conservation work becomes largely the farmer's responsibility, with a minimum of technical servicing.

Public Responsibility in Soil Conservation

Fundamentally, to be sure, the entire conservation undertaking is the farmer's own responsibility, but the farmer needs technical help; and the nation—everybody—has an interest and responsibility in the permanency of the land's productivity. The individual farmer or rancher is the master of his own acreage, and he quite properly should and does stand the expense of those conservation and related improvements which benefit him individually and directly.

However, when we add together such beneficial improvements on thousands of farms, the over-all public benefit may exceed the gains to the individual landholders affected. Government, then, properly should share the responsibility and cost of any country's soil conservation programme. And we have good evidence that this kind of soil conservation pays back through resultant improved business, increased tax revenues, and other channels more than it costs either the individual or government.

In a somewhat different sense, government has an even greater interest and responsibility in the continuing welfare of the land. A farmer has, insofar as he is individually concerned, a lifetime responsibility only; while government has a perpetual interest and responsibility.

International Awakening

An indication as to how this important concept of soil conservation is coming to be recognized widely among our western nations is illustrated in an excellent manner, I think, in the Declaration of Principles unanimously adopted by the Inter-American Conference on Conservation of Renewable Natural Resources, attended by official delegations from 21 American nations at Denver, Colorado, in September of last year.

"Everywhere in the world," this significant pronouncement said, in part, "natural resources have been depleted by ignorant and reckless exploitation that has ignored the inexorable natural laws which maintain them, and this depletion was disastrously accelerated by the recent world war. Throughout the world steadily increasing populations have put an ever increasing strain on the dwindling resources. These two forces, each of which re-enforces the other, have now brought mankind to an almost critical point. The challenge of our time is that we must arrest and reverse them or face the fact that the very existence of civilization will be brought in peril.

". . . The end in view is that people everywhere will understand that their dependence on the earth lays on them the obligation of respecting the earth and protecting it in order that they may enjoy its fullness. *Toward this end it is the duty of governments and their agencies, of religious institutions, of public and private foundations, of universities and colleges and schools, the press, radio and motion pictures to provide instruction that will make clear the penalties of violating the physical laws of nature and the reward of living in accord with them.*"

EROSION PROBLEMS RESPECT NO BOUNDARIES

This potentially historic declaration impresses me profoundly as a practical soil conservation scientist. During the past two-score years, I have worked over most of the United States and have visited a number of other countries. In most places where I have studied the condition of the land, I have been impressed—often shocked—by the havoc that man has wrought in his use and treatment of the land. I have seen costly erosion in every state in the United States, in Mexico and Central and South America, in the West Indies, and over most of Africa. I have talked with or read the reports of others who have visited the ends of the earth. Their observations, and my own, have not revealed many parts of the world that are free from the curse of erosion—a process that respects no political boundaries.

Many of you in attendance at the Pacific Science Congress probably have had similar experiences. Some of our Soil Conservation Service technicians are currently on assignment in various parts of the world to carry on soil conservation study and planning work. And recently Russia announced the undertaking of a major soil conservation programme.

GOOD LAND IS SCARCE IN THE WORLD

And so it goes around the globe — irreplaceable productive soil sweeping off the land in dust clouds or washing down silt-laden rivers to the oceans. Regardless of what you may hear, there is not any abundance of undeveloped land to take the place of that which we have been losing to erosion and unwise land use—and which we are continuing to lose at all too fast a rate. In the world there is left only about four billion acres of immediately arable land, as nearly as I have been able to determine with the information available. That is less than two acres per capita for the present world population of approximately 2¼ billion people, a population that specialists report as growing at the rate of about 20 millions a year. Moreover, much of this limited area of land is only of fair to medium quality. Some of it is poor; and more is being damaged with each year of continuing erosion. The rate of decline has accelerated very greatly during recent years in many parts of the world.[2]

There probably are a number of moderately large areas of land in the world now unproductive that might be brought into productive use. But the precise extent is not known; surveys have not been made. Here and there are some virgin tropical jungle areas that could be used to produce more food, as along the headwaters of the Amazon Basin, the western slope of the Andes,[3] and in the middle Congo. And, of course, there are still some areas in the temperate zones that can be brought into production by clearing, draining, irrigation, or other means. But, even when we consider all these possible sources of new agricultural areas and "rejuvenated" land, we still do not have any surplus for ready use. This means, in my opinion, that we must depend largely on the four billion acres of arable cropland now available for use.

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[2] Union of South Africa Drought Investigations Committee final Report, October, 1923, Cape Town, 1923; Bennett, H. H., Soil Erosion and Land Use in the Union of South Africa, Dept. of Agric. and Forestry, Pretoria, 1945; and Bennett, H. H., Hubbell, D. S., Hull, W. X., Caudle, J. E., Land Conditions in Venezuela and Their Relations to Agriculture and Human Welfare, Soil Conservation Service (multilithed), 1942.

[3] Bennett, H. H., Some Geographic Aspects of Western Ecuador, *Annals of the Association of American Geographers*, Vol. 15 (3), September, 1925.

The Food and Agricultural Organization of the United Nations warns the world in its September, 1948, survey of world conditions and prospects, as follows:

> "The basis of food production is the productive soil of the world, and it is limited in amount. Each year it decreases in quantity and also in quality, through continued use of traditionally bad husbandry practices. . . . The nations are faced here with an issue which cannot be neglected and which cannot be dealt with by the present technical resources of many of the countries where erosion is most serious. The loss of soil concerns the whole of mankind, and it is in the interest of those countries with more experience and resources to put their facilities at the disposal of the less developed countries."[4]

Soil Conservation Spreads Around the World

Fortunately, practical, scientific soil conservation is beginning to spread around the world. There are indications that the tide is turning in favour of conservation and wise use of our land. Therein, I am convinced, lies one of the chief hopes of mankind for future security. Three-fourths of the farmland of the United States and three-fourths of our farms and ranches (large grazing areas) already are within the boundaries of farmer-organized and farmer-directed soil conservation districts, established under enabling laws of all the 48 states, Alaska, Hawaii, Puerto Rico, and the Virgin Islands. Nearly 25 per cent of our farmland has been covered by detailed conservation surveys (approximately 300 million acres) and more than that by reconnaissance surveys (310 million acres).[5] More than 200 million acres have been planned for conservation treatment, and approximately half of that has been treated to date with Soil Conservation Service assistance.[6]

During the past few years, 68 other countries have sent representatives or "trainees" to the United States to study our soil and water conservation programme in the field. Some of these have worked with our technicians for a year or more. These have included agriculturalists and scientists from nearly every part of the globe. In fact, I believe every major country invited to participate in your Seventh Pacific Science Congress has been represented on the list of our soil conservation trainees or visitors. And we, in turn, have profited much in knowledge and experience by sending soil conservation scientists to other countries.

Meanwhile, 49 countries now have sufficient soil conservation work going at home to give them some measure of tangible results. Twenty-one countries, according to our latest information, have organized government agencies for soil conservation—including New Zealand.

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[4] The State of Food and Agriculture, 1948. A survey of world conditions and prospects, Food and Agricultural Organization of the United Nations, p. 24, September, 1948.

[5] Part of the area covered by reconnaissance surveys was later covered by detailed surveys (probably not more than 10 million acres).

[6] Report of the Chief of the Soil Conservation Service for 1948, U.S. Dept. Agr., 1948.

Twelve countries have reported that they are carrying on soil conservation surveys.

HOW ALL NATIONS CAN SPEED SOIL AND WATER CONSERVATION

This is a good beginning. I never would have dreamed 15 years ago that so much progress could have been made in so short a time. But vastly more needs to be done, and speedily, around the world in putting these new-found scientific methods of soil conservation into practical use according to modern soil conservation methods. Therefore, as an essential beginning to conservation of our remaining areas of productive land, I propose, as a soil conservation scientist, that each nation:

1. Make a quick reconnaissance survey of the extent and severity of soil erosion within its boundaries and the extent of the principal areas of fair and good land. Such surveys should be made on the ground, not from the air (although air photographs would be very helpful, especially in developing base maps).

2. Establish in the principal type areas one or more soil erosion research stations to determine: (a) The rates of soil erosion and the amount of water lost as runoff under different kinds of land use, (b) the causes of soil erosion, and (c) the best methods for control or prevention of soil erosion.[7]

3. Establish erosion control demonstration projects of substantial area (something like 10,000 to 50,000 acres in size) in the principal areas having a distinctive regional type of agriculture, to test and demonstrate soil and water conservation measures under practical farming conditions.[8]

4. Develop a national programme of soil and water conservation, including both immediate and long-range objectives, together with a chronology of the actions necessary to reach the objectives.[8]

5. Participate in international activities relating to soil and water conservation and encourage such actions as will facilitate the international exchange of scientific information on the conservation of soil and water resources.

6. Carry on educational work in soil and water conservation with both rural and urban populations, especially through the schools, emphasizing the vital importance of safeguarding our land and water resources.

7. Exchange students and trainees with other countries, particularly those where soil conservation has made good headway and where colleges have included the subject in their curricula as a regular course in conservation.

Only through such actions can we unite our scientific efforts toward sound soil and water conservation technology in positive regional and world-wide actions for human welfare and world peace.

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[7] Report of the Chief of the Soil Conservation Service for 1948, U.S. Dept. Agr., 1948.

[8] Report of the Chief of the Soil Conservation Service for 1948, U.S. Dept. Agr., 1948.

CONSERVING WILDLIFE IN THE NATIONAL PARKS

By Victor H. Cahalane, United States National Park Service

The word "park" covers many degrees of administering the out-of-doors. In the average city park, the environment must be regulated intensively for the accommodation of great numbers of people. In the larger city parks and most state parks, human use is segregated to some extent and much of the terrain is subject to only occasional manipulation. National parks are essentially large areas containing superlative examples of majestic scenery and scientific assets of national importance. These parks can be retained unimpaired for public enjoyment with only the minimum of development for the necessary accommodation of visitors.

This does not mean there is no change. The terrain, vegetation and wildlife are the result of continuing natural processes. All of these processes bring about changes. Necessarily some of these must be destructive. All organisms must eventually give way to make room for successors. Even the so-called "eternal hills" may be altered. As a rule, these changes are gradual and we call them "normal". Occasionally, Nature moves with spectacular speed and the result may be "devastation". In his self-centred way, man is likely to regard volcanism as a wholly destructive and detrimental force. We are prone to forget, in view of flaming slopes and heavy ash falls, that some of the richest soils on earth resulted from volcanic eruptions. When a flood sweeps a mountain valley and levels a "primeval" forest, the public is appalled by the loss of trees and wild disorder of the scene. It is difficult for the layman to appreciate the explanation that successive floods have swept this valley several times during the course of thousands of years, and that as many successive forests have grown and thrived on the nutriments furnished by their predecessors. Each forest in turn has afforded food and shelter to the animals which were adapted to its various stages of plant succession.

As far as possible, animal life in the parks of the United States is permitted to ebb and flow naturally. Except in the few fenced reserves, there is no attempt to stabilize the population of any animal species. The normal fluctuations of numbers must be allowed to continue if the entire pattern of Nature is to be perpetuated.

Biologists are beginning to gain an understanding of population cycles in some mammals and birds. The inevitable fluctuations of such species as snow-shoe hare and grouse are becoming known to the general public. Accordingly there is now little concern because park managers do not institute restoration measures every time that those types of wildlife begin their periodic declines. But in the case of other species whose numerical variations are not understood, park administrators may be tempted to interfere. The tendency is particularly great when a species, whose use of associated animals or plants is noticeable, becomes unusually abundant. Among the notable examples in United States national parks are coyotes, which may temporarily reduce the smaller hoofed mammals; porcupines, which feed on and sometimes kill coniferous trees; and beavers, which may cut down and destroy all food trees and shrubs within about 500 feet of their ponds.

It should not be inferred that management of park wildlife is not permitted. Even in the larger wilderness areas of the U.S. National

Park System, a number of problem species require removal of excessive numbers, or special aids if in danger of extirpation. Most of these problems are caused by man's previous interference with Nature, and must be corrected by man as far as possible. His boundaries may have made the areas inadequate for natural biotic units; his activities may have disturbed the normal relationships of the animals and plants.

In the United States, national parks were at first chosen solely for the protection of scenery. This narrow viewpoint is, happily, widening. The two latest additions to the park system (Big Bend and Everglades) were designed to give the greatest possible protection to an adequate sample of the biology. Because this comprehensive ideal was not fully understood when most of the high mountain parks were exlished, lands not essential to the protection of the scenery were excluded. As a result, although over two million acres comprise a single park, only a portion of the year-long habitats of numerous wildlife species were included.

Many of the widely ranging carnivores leave the parks during their annual winter migrations. Others move out periodically throughout the year in the course of their normally extensive foraging. In the case of the *rare* furbearers, trapping outside of the park boundaries may be almost as disastrous as open poaching within the parks. The greatest possible protection, therefore, must be extended to these species while they are inside the sanctuaries. Any possible disturbance such as construction of developments or ingress of the general public must be anticipated and prevented.

The emigrations of the more abundant carnivores results in a very different type of problem. Livestock interests insist that the national parks breed large numbers of coyotes, wolves, cougars, bobcats (*Lynx*) and other large flesh-eaters that move forth to farms and ranges where they attack and destroy domestic animals and poultry. They declare that these carnivores take up permanent residence and that all efforts to eliminate predators fail because of constant migration from the parks.

While many claims of this type are manifestly exaggerated, preliminary results of research on the migrations of predators indicate that many young coyotes do indeed disperse from their nursery areas. While this dispersal to some extent is haphazard, a strong tendency to move to lower elevations is apparent. If further research discloses that the high mountain parks contribute significantly to re-stocking agricultural lands with predators, suitable control measures must be devised. At the same time, means must be found to safeguard the parks and preserve the normal relationships of wildlife species. The disastrous effects of exterminating predators in the earlier years of national park administration are too evident to permit of repeating the error.

One of the most serious of all park wildlife problems has resulted from the exclusion of vital winter ranges of some of the hoofed mammals. Because a number of other factors are involved, this subject will be brought up later under the discussion of excessive populations.

Species that have been greatly depleted should and sometimes can be assisted back to their normal place in the animal life of the parks.

If a vanishing species can be thoroughly protected from human influence, it often will respond. Sometimes the natural factors that have been exerting an adverse influence can be held in check temporarily. Water supplies can be developed in arid regions. Artificial aid, such as control of natural enemies, should cease as soon as the vanishing species is restored to safe minimum numbers. These aids frequently have undesirable effects on other species and are themselves disturbing to the natural environment.

Once a species has been extirpated, special measures may be necessary to enable a small stock of reintroduced animals to survive and increase to a safe level. Too often, animals are re-stocked in ignorance of the factors which exerted a fatal influence on the original stock. If those factors are still all-powerful, the restoration programme will be a failure.

Although the national parks and monuments are established by law to preserve from change or injury, so far as possible, the matchless natural and historic features and the wildlife therein, great numbers of non-native animals have been allowed to intrude. Grazing exists in nine national parks, sixteen national monuments, and ten other areas. Within these 35 units of the park system, approximately 1,300,000 acres are grazed under permit. The number of livestock that utilize the forage, usually for only a portion of the year, is considerable. In 1947, 1,300 horses, 19,200 cattle, and 33,300 sheep and goats obtained sustenance from the parks and related areas. Most of this grazing (which does not include pack and saddle stock) represents rights that existed at the time that the lands were included in the park system. In the majority of cases, the grazing privileges will terminate with the death of the permittee or his retirement from the industry. Meanwhile, however, domestic stock competes with increasing wildlife populations. Destruction of the ground cover promotes soil erosion, which results in clogging streams and stifling fish and other aquatic life. Pollution caused by the stock is detrimental to watering places. Furthermore, it is presumed that Bang's disease in bison, scabies in bighorn, and perhaps other diseases and parasites in wildlife had their origin in domestic stock. While most of these troubles are susceptible of treatment in domestic animals, they are beyond reach in wildlife due to the impossibility of handling the hosts.

Another problem of intrusion is feral stock. It is firmly entrenched in many of the park areas in the south-western United States and in Hawaii National Park. Burros have found the desert regions so similar to their ancestral Asiatic habitat that they are thoroughly at home. Indeed, they are much more numerous in parts of our south-west than in their original habitat where they are hunted to the point of extinction. Being hardy and wary, burros often become so abundant that they do serious damage to herbs and browse plants, thus depriving the native wildlife of sorely needed forage. Springs and tanks are pre-empted; the limited supply of water is consumed or polluted, and less aggressive creatures are driven away or killed. Use by feral burros may be more detrimental in some areas than licensed grazing by livestock.

Under favourable conditions, domestic goats and swine in the wild state may be even more destructive of natural conditions than the burros. Being highly prolific, they quickly fill their environment and destroy much of the plant life on which native wildlife depends. Furthermore, hogs plough up the ground and feed on the roots, thus accelerating erosion. Being omniverous, they also eat any ground-dwelling animals that they can capture, and devour the eggs and young of birds that nest within reach. This problem is acute in the forested area of Hawaii National Park.

Constant warfare against feral burros is necessary in some of the desert parks and monuments, and against the goats and hogs in Hawaii Park. Hunting with rifles has destroyed great numbers of burros, while driving into traps has had limited success. The animals quickly become gun-shy and very wary, and can be approached within range only by diligent, skilled stalkers. This is time-consuming and personnel and funds for the control programme have been limited. The work is further handicapped by the emigration of burros from non-park lands, where little or no control is practised, into any partial vacuum that might be created. Accordingly, the animals have continued to maintain their numbers in the parks and pressure on forage and water supplies is unremitting.

Only partial relief has been obtained by hunting and trapping goats and hogs in Hawaii National Park. In the dense forests of that area, drives by large numbers of men have been more productive than individual hunting with rifles. Once corraled, the animals are destroyed by shooting. Although thousands have been eliminated in this way, some animals inevitably escape through the cordon of drivers. These individuals, with wanderers from other areas, maintain a constant "seed stock" by which the park lands are soon repopulated. Despite the impossibility of exterminating the feral animals, control must be maintained in order to save the vegetation from even greater damage.

Assemblages of native wildlife in a number of the parks have been further modified by the introduction of foreign wild animals and by American species that did not occur there originally. The ring-neck pheasant has acclimatized itself and has become abundant in a number of areas. When numerous, it cannot fail to have an adverse effect on native birds having similar habitat, food, and other requirements. This pheasant and two others, a quail, two doves, the mynah, and several additional species imported from all over the world, inhabit Hawaii National Park in common with other parts of the Territory. Through competition for food, nesting places and dominance, and by carrying new diseases, some of these birds undoubtedly have played a part in the extinction or marked diminution of a number of the unique native species. Other destructive agents include the mongoose and black rat, which are also introduced species in the Islands.

On the American mainland, mountain goats were planted in the Olympic Mountains by county game authorities in 1927, and are thriving in the national park which was established subsequently. The same species is almost certain to appear in Yellowstone and Rocky Mountain National Parks as a result of recent state stocking in adjacent areas. Additional invasions of other exotic species can be expected as state game departments bring in foreign mammals and birds in an attempt to meet the demands of an ever-increasing army of hunters. Those species which succeed in establishing themselves are likely to spread into the parks and monuments which offer favourable environments. Little or nothing can be done to guard against these threatened invasions or to eject the exotics which already are established.

Some domestic animals have gone wild in the parks, while some wild animals are in danger of becoming tame. Many animals tend to lose their fear of man when they come in contact with him frequently and do not suffer harm as a consequence. Black bears especially are likely to become tame to the extent that blows from clubs and other "mild" efforts fail to drive them away from food stores. This problem, which is not peculiar to the national parks, became severe in a number of these areas. It was the inevitable result of long-time protection of the animals and the attitude assumed toward them by the enormous concentrations of visitors.

Tourists became familiar with park bears acting as scavengers and readily discarded any impression that they were strong, dangerous animals. Furthermore, for many years the park bears were publicized, not as wild forest animals, but as almost-human clowns and beggars. Public familiarity and wholesale taming of bears resulted in an ever-increasing toll of property damage and injuries to people. In 1937, 115 visitors to Yellowstone Park were the victims of undue carelessness and too-close encounters with these powerful creatures. A number of remedies were tried in an attempt to protect visitors and their property, and to preserve the wild character of the bears. All too frequently the problem was "solved" by killing the animals. In 1942, the toll in Yellowstone was 83 bears, 30 of which were the scarce grizzlies. At the end of that year, the Park Service terminated the last "bear show" of numerous animals attracted before seated spectators by offerings of hotel garbage. This step marked an epoch in wildlife management in the parks. It ended a practice that was harmful to the animals and dangerous to the public, besides displaying the bears in an unnatural and degrading manner.

This has been only a partial solution of the problem. Black bears still frequent campgrounds and roadsides, seeking food wastes from garbage cans and hand-outs from tourists. It will be necessary to install modern, efficient methods of collecting and disposing of all food wastes from hotels, lodges and campgrounds in order to avoid attracting bears to areas of human concentration. Means of excluding bears from one or more campgrounds should be devised so that people may be assured of freedom from annoyance or fear of attack by food-seeking bears. Each of these measures will require sizable amounts of money for constructing incinerators and fencing and for proper operation of the facilities. Finally, the park-visiting public must be re-educated regarding the hazards of feeding and even approaching bears, and the harm which is done to the animals by diverting them from their natural mode of life.

While some species of animals have dwindled and in some cases disappeared from the parks, others as here in New Zealand have increased far beyond their normal populations. The causes of these irruptions are usually complex and sometimes obscure. Some of the problems in the United States national parks may have arisen due to destruction of effective predators which formerly served as a check on the increase of herbivores. In other cases, topographic conditions and human developments result in "damming up" excessively large numbers of hoofed mammals which once migrated to distant ranges.

Other problems originate in poorly-drawn boundaries which exclude a large percentage of the ancestral winter range from the park and make it impossible to maintain during the entire year more than a small fraction of the original population. In many instances, matters are complicated by lack of sufficient hunting pressure outside of the parks to stabilize the numbers of migratory game species, and by dispersed control of the animals in their year-round migration cycle.

Park management policy permits of making artificial reductions when a species increases to such levels as to menace its food supply. Solution by natural controls, or by human action outside of park boundaries, is preferred to removing or destroying animals within the parks. Predators, if present in normal numbers, tend to stabilize prey species by removing those individuals that cannot find adequate food and cover. Legal hunting, outside of some parks, if properly regulated and sufficiently intensive, can prevent migratory game from becoming excessively numerous. At times, however, predation does not avert irruptions of prey. Sometimes, state game authorities are unable or unwilling to take action. Over large regions of the western United States, hunting pressure outside of the parks is insufficient to remove excess wildlife populations.

Under such conditions, reductions of park wildlife have been authorized within four natural areas (exclusive of the fenced and closely regulated Wind Cave Park). Two of those (Rocky Mountain and Zion National Parks) involved highly scenic areas of limited extent where visitor use was concentrated. In the third park (Sequoia), relatively small numbers of deer crowded into small wintering areas where they were free from normal predation. In the fourth instance (northern Yellowstone Park), "piling up" of excessive numbers of elk had resulted in severe damage to the park winter range. This in turn created a serious threat to the safety of several other important species of ungulates which were dependent for their existence on the same range. A few other problems of this nature are under observation, to determine if it will be necessary to take action. In numerous instances, it has been decided that the problem was either too local or incapable of satisfactory solution to justify destruction of the animals within the sanctuaries.

Fish life is in a peculiar category in national parks. Hunting of terrestrial animals is prohibited by law and by public opinion. No such protection is extended to the fishes. In fact, most of the acts establishing the various parks contain instructions concerning the taking of fish. These instructions are so definite that fishing may be restricted or prohibited only if it threatens to destroy the resource or to do serious damage to other parts of the park make-up. Even minor, well-justified restrictions which may be imposed to conserve fish species generally encounter the most determined opposition from the angling fraternity. Non-anglers do not protest the killing of park fish as do the non-hunters who vigorously oppose any destruction of mammals and birds.

In order to maintain the supply of catchable fish, park waters have been stocked more or less regularly for many years. In all cases, the objective of stocking was to fill the fishermen's creels at lowest cost. Lack of appreciation for the aquatic environment of the parks, coupled with general ignorance of the biological processes of waters, resulted in serious modification of the fish life. Alien species and races of fishes were planted lavishly and promiscuously. Some of these were not suited to the environment and died out, leaving little or no trace. Others succeeded, crowding out the original inhabitants or hybridizing them. In recent years, disregard of the natural regenerative power of waters and reliance on stocking only catchable-size fish have threatened to impose the ultimate in artificiality.

Park waters cannot be insulated from the terrestrial environment. The effect of destructive modification in any one ecological element inevitably will extend into the other. The most detrimental practices of fishery management must be terminated and other improvements made as rapidly as public opinion and scientific knowledge will permit. Park waters and their flora and fauna should be protected as well as the land and its plant and animal life.

The goal of wildlife management in the national parks is to maintain or restore the primitive relationships between the various animal species and between the animals and their environment. Numerous man-caused disturbances and imperfections in park boundaries, as well as public psychology, render it impossible to rely solely on natural controls. Park wildlife management is faced by many problems. Its greatest need is accurate, thorough information on which to base protection and management.

SOME CONSERVATION PROBLEMS IN HAWAII NATIONAL PARK

By Frank R. Oberhansley, Hawaii National Park, Hawaii, T.H.

Since 1872, when Yellowstone National Park was "dedicated and set apart as a public park or pleasuring ground for the benefit and enjoyment of the people", by Congress, a new type of land use has evolved, a use designed for the nondestructive enjoyment of resources preserved in national parks and other areas administered by the United States National Park Service. These areas contain the nation's most inspiring scenery and sites of great scientific or historic interest.

The basic act of 1916, which established the National Park Service as a bureau of the Department of the Interior, states in part, concerning the management of national park lands, that this Service was designed "to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations". The fundamental principles of administration, protection, interpretation and management of the National Park System, which are based on this policy, have evolved through experience gained over a period of 33 years with little change in original concepts. However, it is obviously impossible for any organization to fully comply with the terms of the act, as any provision for enjoyment of a primitive area by unlimited numbers of visitors must necessarily result in some degree of impairment, and one of the major problems of the National Park Service has been to establish a balance between wise use and preservation of these areas. Against the impact of two world wars and the clamour for such special non-conforming privileges as grazing, lumbering, mining, and other economic uses, national sentiment has supported the basic policy of preserving these superlative areas for the lasting benefit of the millions of people of this and future generations, and most major values which characterize each of our 28 national parks are still intact.

Each of our national parks has special problems of preserving natural values, but Hawaii National Park has many which are unique because of its remote island limitations and the highly perishable nature of its fauna and flora. The park consists of two sections located on the islands of Hawaii and Maui. The Kilauea-Mauna Loa section, named for its two active volcanoes, is located on the south-east side of the island of Hawaii and embraces an area of approximately 305 square miles, extending in a northerly direction from its 26 miles of coast line to an elevation of 13,680 feet on the summit of Mauna Loa. It includes a large part of the dome of Kilauea, the summit dome of Mauna Loa, and a connecting strip between. Because of its wide range in elevation and varied topography there are marked differences in precipitation and temperature which have resulted in diverse types of vegetation and bird life. The Haleakala section of the park consists of 26 square miles on the island of Maui which includes the huge colourful crater for which it is named and a portion of land leading to the summit of the crater rim with an altitudinal range between 7,000 and 10,000 feet.

The major problems concerning the preservation of nature in Hawaii National Park were largely inherited when the park was established. Unplanned development of roads, trails, and structures designed for human convenience with little thought given to the preservation of the primeval wilderness resulted in unrestricted encroachment on the most vital parts of the area. Since the first white man saw the fiery lakes of Kilauea in 1823 the principal urge to visit the area was provided by living volcanoes. With subsequent periods of volcanic quiescence and the gradual loss of wilderness aspects elsewhere, the perishable assets of the region have emerged to a point where they rival the volcanoes for their consistency of interest and inspiration. The volcanic and other geologic features of the park present few problems of protection aside from the preservation of scenic views. Obtrusive structures and poor traffic patterns can be removed or corrected and the area restored with small lasting damage to the volcanoes. But the living wilderness had suffered so severely from the impact of civilization before the park was set aside that many native species of plants and birds are gone forever, supplanted by hardy alien species which are a constant threat to remaining indigenous forms.

The Hawaiian Islands are more widely separated from continental land masses than any other islands in the world. The plant and bird life which became established here ages ago evolved under environmental conditions so different from those on continental land masses that little evidence of their original ancestry remains. Since there were no grazing or browsing mammals the native shrubs and trees developed little or no tolerance for this type of use nor did they possess powers of competition with alien plants which had developed the hardy qualities inherent in such species as have been introduced into their opened habitats by man.

The presence of cattle, pigs and goats has been the greatest factor in the destruction of wilderness values in the park. Cattle and goats had grazed on suitable range lands in the park for almost a century before the park was established, and grazing continued intermittently until June 10, 1948, at which time all cattle were removed, permanently it is hoped, upon termination of a war emergency special use permit. Cattle grazing has centred on the mountain parkland slopes of Mauna Loa between 4,000 and 7,000 feet where luxurious forests formerely grew. Today these forests are represented by scattered groves of decadent native trees which are composed mostly of three species, Koa (*Acacia koa*, var. *hawiiensis*), Mamani (*Sophora chrysophylla*), and Ohia lehua (*Metrosideros* sp.) named in order of palatability to cattle. Other species present were preserved in a fenced enclosure at Bird Park on the lowest part of the range at an elevation of 4,000 feet. The last tree in the park representing the native *Hybiscadelphis giffardianus* died in this vicinity shortly after the park was established. From cuttings taken from this tree before its death only one specimen remains alive at the present time, and this tree, the sole representative of the species, is growing in a poorly kept fenced plot on private land surrounded by hungry cattle. A single break in the fence may result in the death of this young tree and the total extinction of the species. Other rare Hawaiian trees have been reduced to small numbers of individuals as a direct result of cattle grazing.

Acacia koa is the largest and most prominent native tree growing on the parkland slopes of Mauna Loa. By carefully controlled experimental study plots it has been recently demonstrated in the park that reproduction of these trees under moderate use of the range by cattle is impossible and that when these animals are excluded new groves develop with amazing speed. Prior to the exclusion of cattle from Mauna Loa it was impossible to find more than scattered remnants of occasional distress sprouts from these trees. In less than one month after the cattle were removed from the park, reproduction of koa by means of root sprouts was visible throughout the range in the vicinity of parent trees, and at the present time, eight months after cattle were excluded, vigorous reproduction is being established with new growths measured in excess of 4 feet in height.

Mamani is likewise palatable and highly susceptible to cattle and goat damage.

The presence of feral goats in large numbers would be far more serious than that of cattle as these "hoofed locusts" seem able to thrive where larger ruminants starve. Fortunately the goat population on Mauna Loa park land has been reduced to small numbers but constant pressure and upkeep of goat-tight fences will be required to control these pests in this part of the park.

In the semi-arid transitional forest south of Kilauea crater extending into the coastal lowland shrub belt feral goats continue to be a major problem. During 1948 almost 4,000 goats were either destroyed or collected by drives and sold as meat from approximately 70 square miles in this section of the park and in the last decade the numbers so reduced there total approximately 14,000 head. Approximately 800 pigs were also destroyed in the park in the same period. At the present time it is estimated that approximately 1,000 goats remain in this area, roaming in small scattered bands that have become too wary to drive. Consequently they must be controlled by incessant shooting by Park Rangers who are also experimenting with poisoned salt as a control measure. Unfortunately there are large goat-infested areas adjacent to the park which are a potential menace to park lands. Complete co-operation between all agencies concerned is essential to eradicate these animals. The only alternative to preserve the park's vegetation is to maintain at least 50 miles of goat-proof boundary fence.

Wild goats also constitute the major threat to the destruction of wilderness values in the vast and colourful Haleakala crater. Escape facilities afforded the goats by the rugged crater walls make driving exceedingly difficult and incessant patrols through the crater by park rangers and wardens are necessary to protect the rare Silversword (*Argyroxiphium sandwicense*) which is found nowhere else in the world. Approximately 4,200 goats have been destroyed in the crater in the last 10 years. Fortunately the silverswords are less palatable to goats than other available forage but several species of rare trees and shrubs are endangered, with many dead and dying as a result of this pressure. Not content with what foliage they can reach by standing on their hind legs, goats kill many young trees by eating the bark, and on several occasions individuals have been shot out of trees more than 10 feet above the ground. All trees in the crater are goat-liked and little or no reproduction is evident. Lands adjacent to the crater are badly infested with goats whose movements into and out of the crater are entirely unrestricted, and here again the only lasting solution for the problem is vigorous co-operation of all land owners in a campaign that may require shooting, poisoning, and considerable fencing to exterminate these vermin. Goats in Hawaii have no natural checks or diseases and few parasites. Their powers of reproduction are astronomical. They breed at all seasons and the females breed at an age of about six months and appear to give birth to twins on the average with triplets not being uncommon.

Because of inadequate early descriptions it is impossible to determine the full extent of damage that has resulted from grazing in the park. There is evidence, however, that much of the land now barren or covered with weedy shrubs and grasses was once forested and that certain denuded areas have been seriously altered by sheet and gully erosion.

Much of the native ground cover in forested areas consisting of ferns, shrubs and grasses has been replaced with alien species which has had an adverse effect on native birds. Park records indicate that nine species of forest birds were once common in the semi-forested area on Mauna Loa where cattle grazing recently centred. At the present time one seldom sees other than an occasional native bird in the decadent groves of this area, even though several species are common in the immediately adjacent forests of Bird Park where modification of plant life has been less severe. It is thought that radical understory changes induced by grazing have caused this elimination of bird populations. The extremely rare Hawaiian goose or Nene, which is all but extinct in a wild state, was occasionally observed in small numbers on the parkland slopes of Mauna Loa until a few years ago, and grazing has probably been one adverse factor in its habitat. Wild pigs also inhabit the parkland forests and may have contributed to the decline of the Nene by destroying its nests. These animals also live in the dense rain forests windward of Kilauea crater and extend into the fringes of the drier transition forests where they do some damage by destroying ground plants and rooting over tree ferns which they partially consume. They also create conditions which favour invasion by exotic plants. However, their numbers are easily controlled by use of dogs to track them down, and the damage they cause to native forests is insignificant compared with that of goats and cattle.

The forested area of the park windward of Kilauea crater receives an annual rainfall of approximately 100 inches in contrast with 40 to 50 inches on the mountain parkland slopes of Mauna Loa and 15 to 35 inches in the drier transition forests to the south. These rain forests are characterized by dense semi-tropical growths dominated by Ohia-lehua and tree ferns and they are the least modified areas in the park. However, the extent of these forests within the park boundary is too limited to assure their permanent preservation and it is proposed to extend the northern boundary of the park to include the as yet unspoiled contiguous unit of this forest as a buffer area against the jarring influence of human encroachment. Penetrating this wilderness with roads and trails, clearing sites for summer homes and vegetable gardens, and—what is more alarming—the wholesale removal of tree ferns to support expanding orchid growing enterprises and a new industry which makes use of the juice of tree ferns as an oil emulsifier in poison sprays for cane and pineapple fields, will result in almost complete annihilation of this forest under present management. The inherent wilderness assets of this area are far more important than any immediate gains which might accrue to a few individuals. It is truly a national asset and represents the only opportunity of saving a remnant of unspoiled Hawaiian rain forest of this type for posterity.

Before the park was established several summer homes were constructed in cleared spaces in the forest near the north rim of Kilauea crater. The houses have long since been removed, but growths of blackberries, tibouchina, guava, and other exotics creeping outward from these sites require incessant control measures to permit native plants to re-establish themselves and dominate these small areas. Constant control measures are also necessary along roadsides and trails to control particularly obnoxious exotic plants as they appear.

During the recent war considerable damage resulted from training manoeuvres by tank corps and other units in the park. A bombing range of several thousand acres was also used by Army and Navy forces. All points of access to these areas have been sealed, duds have been disposed of, and nature is gradually healing these scars of war, which fortunately were confined to the more barren parts of the Kau desert. Several unsightly and obsolete structures are still being retained in standby condition by the armed forces, notably at the highest and most conspicuous point on the crater of Haleakala where they mar the view from every point within the crater.

By virtue of its remoteness from large centres of population Hawaii National Park has not suffered from unprecedented numbers of post war visitors as has been the case in national parks on the mainland. Consequently the impact of visitor use is much less severe, which is fortunate, as the park is sorely in need of recuperation following the intense use by hundreds of thousands of military personnel during the war years.

A poorly designed and incompleted travel pattern complicates the enforcement of park regulations. An eleven mile section of the main Round-the-island highway passes through one of the most vital areas of the park, including a portion of the outer crater of Kilauea crater.

Side roads branch from this main artery within the park at eleven different places. Plans have been prepared to realign this highway in such a manner that it will bypass all but a one-mile strip of the park across the narrowest part of the Mauna Loa Corridor, thus eliminating undesirable heavy trucking and other non-park traffic.

A certain percentage of the visitors to national parks have not learned good out-of-doors manners. Some of them dispose of cleaning tissue, picnic boxes, newspapers and other trash along the highways from moving cars, or leave picnic areas littered with refuse. Others leave their initials on trees, signs and other structures. Thoughtless destruction of rare plants by vandals has been common for many years in Hawaii National Park. New stipes have been broken from tree ferns year after year causing the death of many of these plants at important focal points and acres of ohelo berry bushes have been pulled up to procure the berries when ripe. Unscrupulous fishermen persist in the destruction of rare marine life adjacent to park shorelines by blasting.

Positive corrective measures are under way which it is hoped will result in saving endangered species and hasten restoration of depleted areas. A small nursery has been established and through the co-operation of the Territorial Division of Forestry and Agriculture it is hoped that the single *Hibiscadelphus giffardianus* can be re-established in sufficient numbers to guarantee its safety. Other rare tree species (including *Fagara dipetala*, var. *geminicarpa,* represented by nine living specimens, *Ochrosia sandwicensis,* extinct on Hawaii Island but present on Maui, *Urera sandwicensis, Rubus macraei, Fagara mauiensis,* var. *anceps, Charpentiera obovata*) are to be re-established in the park through nursery stock.

On July 1 it is planned to employ permanently a well trained Biologist whose whole time and efforts may be devoted to establishing a systematic conservation programme that will result in placing our vanishing species of rare bird and plant life on secure ground.

In spite of this rather pessimistic account of some of the conservation problems of Hawaii National Park, the major assets of the area which existed when the park was established are still intact and many of them have been saved from total loss. The geologic aspects of the three great volcanoes remain essentially unmodified by man, and only a month ago it was my good fortune to stand on the crater rim of Mauna Loa and witness the spectacular and inspiring eruption of the greatest of all volcanoes. This vast mountain is entirely worthy of national park status in its own right.

PROGRESS IN FORESTRY IN THE UNITED STATES

By Lyle F. Watts, Forest Service, United States Department of Agriculture

Of all the regions of the United States, the Pacific Northwest, California, and Alaska are of especial interest to the Pacific Science Congress. The original forests of these regions were perhaps the finest that the world has known. Today these regions contain the bulk of the virgin commercial timber remaining in this country. They are of major importance in the forest economy of the United States. They have also had a prominent part in the timber trade of the Pacific.

To get perspective on forestry in the Pacific Coast regions of the United States, it is necessary to consider two aspects of the forest situation for the country as a whole:—

1. The trend of forest depletion: our timber supply is waning.
2. Constructive developments: there is more forestry in the woods today than ever before, both public and private.

THE TIMBER SITUATION IN THE UNITED STATES (ALASKA NOT INCLUDED)

The United States has plenty of forest land, if well managed, *ultimately* to grow all the timber products it needs, with a margin for unavoidable losses, new uses, export, and national security.

Of the 624 million acres of forest land, 461 million are classed as "commercial" because they are capable now or prospectively of producing merchantable timber and are available for that use (Table 1). But our commercial forests are badly run down. About 16 per cent (75 million acres) is idle — denuded or so poorly stocked with seedlings and saplings as to be unproductive for decades (Table 2). One-third of both the pole-timber and second-growth saw-timber acreage is poorly stocked. Destructive cutting, fire, and "high-grading" have replaced valuable timber with inferior growth. Only one-fourth of the 45 million acres of virgin timber left is of high quality; more than a third is of doubtful commercial value.

TABLE 1.—FOREST LANDS IN THE UNITED STATES, 1945

Region	Total	Commercial	Non-commercial
		Million Acres	
North	211·8	170·3	41·5
South	186·8	183·3	3·5
West:			
Pacific Northwest[1]	53·8	46·2	7·6
California	45·5	16·4	29·1
North Rocky Mountain	53·2	29·0	24·2
South Rocky Mountain	72·7	15·8	56·9
	225·2	107·4	117·8
United States	623·8	461·0	162·8

[1] Washington and Oregon.

TABLE 2.—COMMERCIAL FOREST LAND IN THE UNITED STATES, BY GROWTH CLASSES—1949

Growth Class	Million Acres
Saw timber:	
Virgin	44·6
Second growth	160·6
Total	205·2
Pole timber	95·0
Seedlings and saplings, fair—and well-stocked	85·5
Poorly stocked seedlings and saplings and denuded	75·3
Total	461·0

Despite some significant gains, the forest resource situation, generally speaking, is still on the down grade. One expression of this is the supply of all-important saw timber. Originally we had at least 8,000 billion board feet. We now have less than 1,600 billion, and this is not well distributed (Table 3). About one-third is concentrated on the 6 per cent of the commercial forest land in western Washington and Oregon. The East, with three-fourths of the commercial forest land, does not have enough growing stock to sustain for long its present output. We can no longer think of our standing timber as a "reserve". It must be considered as active capital and we must recognize that the annual timber yield depends upon the amount of this capital or growing stock. The volume of saw timber in 1945 was 43 per cent less than reported in 1909 and 9 per cent less than in 1938. Just as important, the quality and size of the timber are deteriorating.

TABLE 3.—SAW-TIMBER STAND BY REGIONS—UNITED STATES, 1945

Region	Timber Stand, Billion Board Feet	
North		220
South		338
West:		
Pacific Northwest:		
Douglas-fir subregion	505	
Pine subregion	126	
California	228	
North Rocky Mountain	127	
South Rocky Mountain	57	
		1,043
United States		1,601

TABLE 4.—FOREST DRAIN AND GROWTH—1944, POTENTIAL REQUIREMENTS AND GROWTH GOAL, UNITED STATES

	Saw Timber	All Timber
	Billion bd. ft.	Billion cu. ft.
Annual drain		
Lumber	34·4	6·7
Pulpwood	4·8	1·3
Fuel wood	3·9	2·2
Other products	6·6	2·0
Total commodity cut	49·7	12·2
Losses from fire, insects, diseases, etc.	4·2	1·5
Total drain	53·9	13·7
Annual growth	35·3	13·4

We are overdrawing our forest bank account. Nationally, the 54-billion-board-foot saw-timber drain (cut plus natural losses) in 1944 exceeded annual growth of 35 billion board feet by 50 per cent (Table 4). Because of the backlog of virgin timber, the overcut is not necessarily dangerous in the West, but continuation of the present rate of saw-timber cutting in the East means depletion of forest capital and will be at the expense of future yields there. A near balance between cubic-foot drain and growth for all timber including trees below saw-timber size is misleading, because 80 per cent of the drain is in saw timber, particularly softwoods, whereas much of the growth is in small low-grade trees and inferior hardwoods.

The intrinsic needs of this country for timber products are considerably greater than the present cut. The heavy demands of a war economy focused the spotlight on the adequacy of our timber supplies—an inadequacy long foreseen but delayed in its impact by lagging consumption during the depression thirties, and masked during the war by shortages of manpower and equipment which hampered output. Currently, production of lumber and other saw-timber products is being held down by the growing scarcity of suitable accessible timber. Even pulpwood is in short supply in some important regions. Timber shortage is clearly reflected in lumber prices which have outstripped those of other building materials. Lumber prices in June, 1948, were 313 per cent of what they were in 1926, whereas all building materials had only risen to 197 per cent.

This country could grow a lot more timber. Careful study—looking beyond current limitations to long-range needs because forestry, like the nation's growth, is a long-time proposition—indicates that an annual crop of 65 to 72 billion board feet would be a reasonable goal of annual saw-timber growth. This is a big order. It is about double the present saw-timber growth. Even if there could be prompt and widespread adoption of good cutting practices and of other forestry measures—which is not likely to be the case—it would probably take until the end of the century to build up the growing stock needed to sustain such a goal.

Highlights on Pacific Coast Regions

In the national situation that has been briefly sketched, the United States must draw heavily on its Pacific Coast forests in the years ahead. Additional details on the forests and the forest products industries of the Pacific regions will help in an evaluation of progress in forestry during recent years.

The Douglas-fir Subregion

Of prime importance are the great Douglas-fir forests which lie between the Pacific Ocean and the crest of the Cascade Mountains in Washington and Oregon. This narrow strip of territory—little more than 100 miles in width and 500 miles in length—contains only 6 per cent of the commercial forest land of the United States. Yet it currently supplies almost one-fourth of the output of forest products and has almost one-third of the saw-timber stand.

The Douglas-fir forests are characterized by timber of large size occurring in dense stands, averaging 38 thousand board feet per acre. The climate is moist and timber growth is generally rapid. In some young stands of western hemlock-Douglas-fir along the Oregon coast growth averages 2,000 board feet per acre per year. On average sites in the Douglas-fir type mean annual growth in fully stocked second-growth stands up to 140 years of age is over 600 board feet per acre (Scribner rule).

Logging in the big timber and rough topography of this region requires heavy equipment and challenges the ingenuity of the engineers. Large-scale operations were at first dependent upon steam engines and wire cable for skidding and loading logs in the woods and on railroad transportation from woods to sawmill. Now, however, crawler tractors with specially designed arches are commonly used for skidding, and water trucks are replacing railroads for log hauling.

Sawmill capacity in the region, based on rapid exploitation of the virgin timber, is greatly in excess of the sustained-yield capacity of the forests. The demand for sawlogs is accentuated by the predicament of the young and rapidly-growing plywood industry, which is already faced with acute shortage of the high-quality logs it can use to best advantage. A large pulp and paper industry has also grown up in this region, based primarily on the use of spruce and hemlock, but now expanding into processes using Douglas-fir sawmill waste.

California

The forests of California, though more varied, are similar to those of the Douglas-fir region in that the timber is large, the topography generally rough, and logging largely dependent upon heavy power equipment. California's forests may be grouped into four distinct types: the ponderosa and sugar pine forests chiefly in the Sierra Nevada Mountains; the Douglas-fir forests of the north central portion of the state; the redwood forest of the northern coast region; and the noncommercial chaparral of southern California. About half of the forest land in California is publicly owned.

Lumbering activity is chiefly in the pine forests. More heavy cutting and uncontrolled fires in the past have resulted in the conversion of much potentially productive timberland to worthless brush. Where the forests are mixed, removal of the ponderosa and sugar pine has often left the land in possession of the less valuable white and red firs.

The reduced forests, although limited in area, are of special interest because of the huge size of the trees. Except for small areas reserved as parks, the redwood forests are privately owned. The ability of redwood to sprout vigorously from the old stumps simplifies, but does not solve, the problem of keeping these lands productive.

The Douglas-fir forests of California do not measure up to those of Oregon and Washington. The stands are generally lighter and the trees smaller and of poorer quality. The country itself is for the most part rougher and more difficult to operate. Although there has been little commercial logging in these forests in the past, they are now being opened up. Most of this type is in the National Forests.

The mountains of southern California are clothed with a chaparral forest of no value for timber production but of great importance for watershed protection. The economic life of the great citrus fruit industry and of the rapidly-growing urban population of that part of the state is dependent upon the adequacy of the water supply which comes from these brush-covered mountains.

Alaska

The accessible commercial timber of Alaska occurs in a narrow fringe on the lower slopes of the mountains along the tidewater of the south-eastern portion of the territory. Most of it is in the National Forests. The bulk of the stand is western hemlock, intermixed on the better sites with Sitka spruce—often of large size and high quality—and some cedar. It is unlikely that any great portion of the forest of the vast undeveloped interior of Alaska can be opened up for commercial use.

But the forests of south-eastern Alaska are well suited for the manufacture of high-grade pulp, and eventually should be able to supply 1,500,000 cords of pulpwood annually, all of which is likely to be in demand for use in the United States. The first contract for the sale of timber and the erection of a pulp mill in Alaska was signed in 1948.

Elements of Progress in Last Decade

To evaluate recent progress, I revert to the national situation.

World War II has profoundly affected American forestry. It gave us more and higher aims for peace, and left no doubt that a stable, high-level economy with jobs for all would call for full use of all basic resources, including our forests, and for the development and perpetuation of those like forests that are renewable. It brought us face to face with timber shortage but stimulated more efficient and diversified use of wood. It taught how essential forests are to national strength. It emphasized the importance of an adequate and well-distributed growing stock and put a premium on accessibility and quality.

The huge war and post-war demand for lumber with resulting high prices has opened the way for economic use of much timber that was formerly wasted or could not be harvested. Inferior species, such as lodgepole pine and the true firs in the West, for which there was barely any market before the war, are now being handled profitably. In mixed forests this is a great help in giving the forest manager better opportunity to control the composition of the residual stands and the conditions for reproduction.

Better markets are also stimulating closer utilization in the Douglas-fir forests. Trees too small for economic handling by the heavy power equipment needed for the best of the timber are now frequently taken out with special equipment in advance of the main logging operation. Light logging equipment and portable mills are also being used after the main logging job to clean up small and broken material that would otherwise be wasted. This closer utilization, in a type commonly calling for clear cutting, reduces fire hazard on the cut-over areas and makes for more satisfactory reproduction.

Also facilitating good forest practices is the increased use of tractors and trucks for logging instead of power skidders and railroad transportation. Tractors and trucks permit much greater flexibility in operation. They make selective cutting practicable and give greater latitude in planning the layout and season of operations. On the other hand, their very efficiency has led to much premature and destructive cutting of young timber that formerly could not be handled at a profit. Premature cutting is an old story in eastern United States but it has only become a problem in the West in recent years.

Although long-range research activities were greatly curtailed during the war, progress in research is one of the most significant aspects of the past two decades. The nation-wide forest survey—started in 1930—had covered the South, the Lake region and the Pacific Northwest before the war broke out. It is now being extended to the rest of the country. Forest and range management research has been greatly expanded and has greatly strengthened the technical foundation for sound policy and management.

These lines of research are being brought closer to local needs by decentralization in a number of new research centres. Watershed research has been given new significance by the need for factual information upon which to base sound flood control programmes, and by the growing realization of the vital part water resources play in the future welfare and economic development of our western country. The fund of technical knowledge built up by the Forest Products Laboratory proved invaluable during the war. Research in forest products has also come to the fore in its promise of new uses for wood and new products from chemical conversion of wood.

With private timber playing out, the public forests are assuming a more important place in our current timber supply. This is of especial significance in the West where more than half of the remaining saw timber is in public ownership. Prior to 1940, much of this timber, in response to economic circumstances, was in a stand-by status. Now, however, national forest timber is being opened up as rapidly as possible for commercial use, within the sustained-yield limits of each working circle. Output has tripled, rising from 1·25 billion board feet in fiscal year 1939 to 3·8 billion in 1947 and 1948. It can be increased further—eventually doubled—but this will require a greatly enlarged and far-flung road-building programme to gain access to undeveloped areas.

The better to protect national forests from fire, the Forest Service has continued to develop new equipment and new techniques. Noteworthy achievements in the past decade have been a specially designed trail-building tractor and a "mechanical mule"—a two-wheeled tractor unit for hauling freight over mountain trails. Most spectacular has been the use of airplanes in fire control; first to transport equipment and supplies to inaccessible places, and more recently to drop firefighters near incipient fires by parachute.

The integrity of our great national forest system in the West was attacked during 1947 by certain livestock interests which sought to have national forest ranges turned over to the states or sold to the users at nominal cost. This move to dismember the public forests aroused public sentiment and appears to have been successfully withstood. Actually, long-range public interest calls for expanding the acreage of the national and other public forests.

One of the most encouraging developments of the past decade has been an awakening of interest in forestry by private forest land owners. To a large extent this has been brought about by the great demand for lumber, rapid expansion of the pulp and paper industry and concern of many operating companies for a continuing source of logs and pulpwood. There are, of course, numerous examples of long-range forestry planning by forest industries running back 20 or 30 years, but only within the past 10 years has the leadership of such pioneers been followed to a significant extent by any large segment of the forest products industries. One indication of recent interest is the "Tree Farm" movement, started in the Douglas-fir region in 1941 and now sponsored nationally by American Forest Products Industries, Inc. As of January 1, 1948, almost 15 million acres of commercial forest land—about 10 million in the South and 5 million in the far West—had been dedicated to planned timber growing under this programme by more than 1,000 owners. This acreage is less than 5 per cent of the commercial forest land in private ownership, but it does not by any means include all the properties which are under some form of forest management.

A field survey by the Forest Service in 1945 for the first time afforded a comprehensive view of the status of forest management in the United States. This survey showed that about two-thirds of the cutting in private forests still had to be rated poor and destructive, and so would not keep the land reasonably productive. However, it showed that 29 per cent of the cutting by large private owners (those with over 50,000 acres each) was good or better—while only 32 per cent was rated poor or destructive. In the South, which has about half of the private forest land, more than half of the cutting by large owners was good or of high order; in the West, only 9 per cent was so rated. Among the large owners the pulp companies as a group are doing better than the lumber companies. However, lumber and pulp companies together own only about 15 per cent of the land in private ownership. On the small holdings (less than 5,000 acres each and averaging 62 acres), which comprise 75 per cent of the private lands, only 4 per cent of the cutting is good or high order. Clearly private practice on the whole still has a long way to go.

Behind the awakening of interest in private forestry and paving the way for it lie a number of public programmes. Most important of those is Federal co-operation with the States in forest fire protection. Steady progress has been made in increasing the area under organized protection and in improving the protection on lands previously organized. In 1947, protection had been established on 328 million acres of State and private lands, but it was still needed on 111 million acres. In 1935 only 241 million acres were protected.

The Forest Pest Control Act of 1948 provides new authorization through which protection from insects and disease can be placed on much the same basis as fire.

A major development affecting forestry on small holdings is the Norris-Doxey Act of 1937, under which the Federal Government cooperates with the States in providing technical assistance to farmers in the management of their woodland and the marketing of forest products. In 1938 some 173 projects, each with a resident forester, were in operation under this Act in 40 States. Similar assistance on a small scale is also given by Soil Conservation Service foresters in cooperation with soil conservation districts and other public foresters. Another measure to facilitate good forestry on private lands in conjunction with interrelated Federal lands is the sustained-yield unit act of 1944. This authorizes agreements under which operators may get the privilege of purchasing national forest timber at appraised value without competition in return for committing their own lands to a coordinated plan for sustained-yield management.

While public aids such as these will always be a major part of a comprehensive forest programme, there is need for public regulation of cutting and other forest practices on private forest lands. The case for stronger public action than we have had in the past is being built up by continued depletion of our timber supply, increasing concern about watershed protection and mounting evidence that for the bulk of the private land good forestry will in the long run pay its own way.

Chiefly within the past decade 15 States have enacted legislation dealing with forest practices in one way or another. The laws have remained inactive in several of the States and the standards have meant little in others. Nevertheless, the need for a good regulatory legislation has been widely recognized and serious efforts at administration have been made in a few States.

The States should continue to have opportunity to enact and administer adequate regulatory laws. However, in order to assure a consistent pattern—nation-wide and in a reasonable time—a basic Federal law is needed. This basic legislation should establish standards as a guide for local forest practices and authorize Federal financial assistance to States which enact and administer regulatory laws consistent with the Federal requirements. It should also provide for Federal administration in States which request it or which, after a reasonable period, fail to put such regulation into effect. It is not suggested that such legislation would require sustained-yield management. Indeed, so long as cutting practices attain the required standards, it would not regulate when, or how much any owner might cut. But it should stop further forest destruction and deterioration and so help maintain a reasonable growing stock as the basis for future production.

Other Aspects

This paper has dealt primarily with forests from the standpoint of timber supply. But the forests also contribute to the welfare of the nation in other ways.

They are invaluable in the protection of watersheds. In much of our western country the forest lands are, in fact, more important as sources of water than for timber supply. Water from forest lands is the lifeblood of irrigation agriculture. It is a critical factor in the life of many western cities and communities. It is the chief source of power for the growth of industry in the West. Conversely, destructive waters are of equal concern. Floods exact a heavy toll and sedimentation impairs the usefulness of our reservoirs. We need to be sure that in the management of our forest lands the water resource will be protected and developed.

Our western forests provide range forage for millions of livestock. Range use is of most importance in the interior basins, but is significant for the Pacific Coast regions as a whole because of its influence on the watersheds.

The forests—especially the public forests—also afford recreation and sport for people in all walks of life. They are the habitat of much of our big game and other form of wildlife. Recreational use of our forests is of growing importance, in winter as well as summer.

Fortunately, good timber management usually enables the forests to meet related needs as well. Nevertheless, measures aimed at timber production may need to be modified in some cases to prevent soil erosion and safeguard watershed, range, scenic, recreational, or other values. And protection or development of such values often call for supplementary measures which may not be related to timber production.

Looking Ahead

The increasing population and rapid growth of industry in our Pacific Coast regions are steadily raising local consumption of wood. For example, California now leads all the States in lumber consumption. This means more interest in forestry and better opportunity for profitable forestry. But it also means higher prices for timber products and less timber for export in the years ahead. Nevertheless, in our Pacific Coast forests, we have the opportunity to show what good forestry can do when applied in virgin softwood territory before destructive exploitation and fire have run their course. If American forestry achieves the goals suggested in the first part of this paper, our Pacific Coast forests should be able to continue to contribute in a significant way to the needs of other countries of the Pacific for softwood lumber and other timber products.

PROGRESS IN MANAGEMENT OF LARGE MAMMALS WITH SPECIAL REFERENCE TO THE WAPITI IN JACKSON HOLE

By Olaus J. Murie, The Wilderness Society, U.S.A.

In the relatively short period of time during which the North American continent has been occupied and economically developed, we have had an excellent opportunity to view the evolution of modern principles of wildlife management. I should like to discuss briefly the wapiti of North America, and somewhat more specifically the wapiti of the north-west corner of the State of Wyoming, as an illustration of the trend in their conservation and management.

In primitive times the wapiti, or elk as they are called in America, occupied the North American continent from the Atlantic to the Pacific Coast, and from parts of Canada south to Mexico, in all suitable habitats. The changes in their status that have taken place during the settlement of the country may perhaps be thought to centre about at least three important events that greatly affected our big game species.

First came the great slaughter of game that occurred during the middle of the nineteenth century, as people crowded westward toward the Pacific Coast. The buffalo and the pronghorn all but disappeared from the plains. The wapiti had early disappeared from the eastern half of the United States, and soon became scarce in most western localities as well. A few herds survived, however, in and near Yellowstone National Park and a few other retreats in the Rocky Mountains; also in the dense forests of the Pacific Coast from northern California to British Columbia.

Then came the second significant event, which developed around the turn of the century. This was a general public awakening to the danger of extermination. The wapiti, pronghorns, mountain sheep, and other big game were given more adequate protection. Furthermore an elk restoration programme was begun, which resulted in putting elk back into many ranges where they had disappeared. As we all know, wapiti were even shipped to New Zealand and became established here on the South Island. Once more these animals were widely distributed and had been saved from extermination.

The third significant event that affected our wapiti was the rapid settlement of the country, resulting in the use of former game winter ranges for farming and the grazing of domestic livestock. We had saved our elk herds from extermination only to find that it was becoming difficult to find a place to keep them. This was actually the hardest situation that conservationists had to face. The largest remaining group of wapiti, numbering something over 20,000, became known as the Jackson Hole elk herd, located in the north-west corner of Wyoming, and its problem occasioned country-wide attention. The Federal Government purchased private lands to form the nucleus of an elk refuge, where elk could graze in winter and where hay could be put up for winter feeding. This original acreage was augmented by a generous donation of land purchased by the Izaak Walton League of America. Later more extensive Federal purchases were made, until today the National Elk Refuge in Wyoming consists of upward of 25,000 acres. Furthermore, some adjacent lands, and hay resources, have been made available to these animals by land purchases made by Mr. John D. Rockefeller, Jr., for national park purposes. And the State of Wyoming purchased some small tracts for winter feeding.

It should be understood that these areas are for winter use only. The wapiti spend the summer season in the mountains some 60 miles to the north. When the winter snows cover the mountains the animals make the long migration south to the lower winter range.

The National Elk Refuge is administered by the United States Fish and Wildlife Service (formerly the Bureau of Biological Survey), whose responsibilities include research and the nation-wide administration of a system of wildlife refuges. The elk refuge, acquired in the earlier years to meet the emergency, was devoted primarily to raising hay to feed the elk in winter when snow drove them down from the mountains. The refuge lands also furnished natural grazing, and here was available, in addition, considerable winter range on the adjacent national forest.

This should have solved our problems, but it didn't. We were still losing elk in winter, as much as ten per cent, even though they were given all the hay they could eat. The Bureau of Biological Survey then established a research project to make a comprehensive study of the life history of the wapiti, as a basis for an effective management plan. The work was begun in 1927 and continued for several years, and I was fortunate enough to be assigned to the task.

The first year revealed some of the basic causes for the annual winter losses. It was learned that the animals were being infected with necrotic stomatitis, a mouth disease that has also been common among livestock. It was found that a dangerous grass, *Hordeum jubatum*, was present in the hay, as well as a smaller amount of cheat grass, *Bromus tectorum*. The sharp seeds and awns of such grasses cause lesions in the tender tissues of the mouth, which are then infected with necrotic stomatitis. In the case of wild game that cannot be treated, the disease is usually fatal. The aged animals and the calves were the classes that suffered the greatest loss.

Further study revealed the fact that on natural browse range, where no hay is fed, similar losses occur when there is an overpopulation of animals. This appears to be caused by the fact that too many animals on a given area will eat the twigs down to an abnormal thickness, and the coarse, splintery material injures the mouth. There is evidence, moreover, that any coarse, brittle, dry forage is dangerous to the animal. There is the further possibility that ground on which thousands of animals are concentrated year after year, such as a feed ground, may become unduly contaminated with disease organisms. There is, finally, the factor of susceptibility, or recuperating power, in animals somewhat undernourished on a crowded range.

Meanwhile, another problem had arisen, and it was by no means confined to the elk. With years of protection of game animals, and a shrinkage of original game range, a serious over-population had developed. This was true of white-tailed deer, mule deer, and elk, and applied particularly where the animals were dependent on browse. This resulted in a dwindling of forage resources, and malnutrition and death of animals.

The elk, or wapiti, is omnivorous in its choice of food plants, and will feed on grass, browse and other plants. It was learned, however, that where browse is available in winter the elk will eat it, whether or not other forage is present. They will eat browse even when an abundance of hay is given them. The result is that where elk in large numbers are being fed hay year after year the shrubs and young trees in the area will suffer. On the National Elk Refuge certain palatable shrubs, including willows, virtually disappeared from the range, and there was damage to forest reproduction, particularly the palatable firs. As the mature aspens and cottonwoods died, there was no replacement by new growth, for the young shoots were persistently eaten down each winter. In other words, by maintaining a herd of elk larger than the range would normally carry, through the expedient of feeding hay, we were gradually depleting the range and making it much less productive of forage.

In the meantime the trend I have outlined was becoming apparent in many parts of the country on deer and elk ranges. In a period of relatively few years, when soil protection and ecological balance between animals and food supply have forcibly held our attention, the principles mentioned here have been accepted by wildlife technicians as elementary and basic. They have not yet been accepted by the general public.

In the administration of the National Elk Refuge full advantage was taken of every advance in our knowledge of ecological factors. Experimental facilities were established to study nutritional requirements. An elk-proof wire drift fence several miles long was built to keep the animals from moving over to certain cattle ranches, where formerly they had been in the habit of raiding haystacks. Feeding grounds were changed from year to year. And the State of Wyoming agreed to a reduction of the elk herd to what we believed to be the natural carrying capacity of the area in winter, a total of about 15,000 elk, of which about 7,000 come to the National Elk Refuge in winter.

More recently we believe we have made a further advance. For years we had noted the winter losses, about ten per cent, whenever we fed hay for any length of time, while during periods when elk grazed naturally the losses were very light. Apparently the moist forage taken naturally where it had grown, in the snow, caused no mouth injury. Accordingly, a few hay meadows were left uncut in the fall, for the elk to harvest naturally when they came down from the mountains. The results were promising. Then last year, and again this year, all the hay fields of the Elk Refuge were left uncut. With co-operation of the State Game and Fish Commission and Mr. Rockefeller, hay was obtained elsewhere with which to fill the refuge hay sheds for emergency use.

So far this new venture has worked very well. The elk have remained scattered and the losses have been negligible. The animals have been kept reasonably active seeking their food, which should keep them in a healthier condition. Since the original winter range of this elk herd has been converted to use by livestock, and the National Elk Refuge and the surrounding area are subject to heavy snowfall at times, there may be a need to keep hay on hand for emergency feeding. But we are hopeful that the new grazing programme we have begun will eventually help to eliminate some of the evils of an established hay feeding programme.

Our experience with wildlife management in America has taught us much. Fundamentally it has taught us that in a region where snowfall is a limiting factor the available winter range is the measure of the game herd that it is possible to maintain. We have learned that wildlife management is a land use problem and that provision should be made for wildlife in the administration of public lands. The national forests and public grazing lands, contain much of our game range. National parks furnish habitat for all forms of wildlife, and various state and other parks contribute to this purpose. Of great importance is the nationwide system of Federal wildlife refuges, which have been specially provided to give sanctuary and nesting places for waterfowl and upland birds, and permanent habitat for such mammals as wapiti, pronghorn, mountain sheep, and other big game. I would stress again that wildlife management is land management, and is dependent on designated land use.

In our experience with wapiti in North America we have found that their value, in their own vigour and in their appeal to sportsmen or to others who enjoy seeing them in the wild, is enhanced by whatever degree of primitive environment we are able to save for them. In such environment they have infinitely more value to the ecologist or any other applicable branch of science. Observation of the animals in such environment has more zest and significance to those who seek them for recreation or understanding. I would mention that the Jackson Hole elk herd that I have referred to specifically spends the seasons of spring, summer, and autumn in the southern part of Yellowstone National Park and a portion of the adjacent national forest that has been officially designated as a primitive area, in which no roads are to be built. This furnishes an ideal natural home for the wildlife, relatively undisturbed by traffic.

My discussion has centred chiefly around the National Elk Refuge. In that area the Fish and Wildlife Service has only the responsibility of caring for the elk in winter. But the policy that has been developed tends to keep the animals healthy and as close to their original habits as the particular circumstances permit.

Nations who are concerned with wildlife conservation may learn from one another. We in America are eager for every opportunity to observe conditions in other countries. The present Science Congress here in New Zealand offers such an opportunity. And we are particularly happy over the international aspect of present day efforts for the "Preservation of Nature".

The Fish and Wildlife Service, and The Wilderness Society of America, whom I am privileged to represent here, pledge their support and co-operation in such worthwhile international efforts in conservation.

Note: The data on which this paper is based was obtained while in the employ of the U.S. Fish and Wildlife Service.

A CONSERVATION PROGRAMME FOR MICRONESIA

By F. R. Fosberg, George Washington University, Washington, D.C.

Under the trust agreement between the United States and the United Nations, that portion of the widespread island region termed Micronesia that was formerly under Japanese mandate has been, since July 18, 1947, governed by a Civil Administration set up by the United States Navy. This administration has accepted the task of fostering the conservation of the natural resources and features of especial interest in the area as one of its duties.

For advice on conservation problems, the administrative authorities turned to the Pacific Science Board of the National Research Council, which, in April and May of 1948, held two conferences of interested persons and competent authorities to formulate a programme.

The area under consideration includes the Marshall, Caroline, and Marianas archipelagoes. Included are high islands of several kinds, limestone, volcanic, and mixed, and low islands of all climatic types from the arid northern Marshalls to the lush jungle-covered rainy atolls of the central Carolines. The conservation situation here is of particular interest because it forms an excellent microcosm experiment illustrating conservation needs and problems of the world in miniature. It is entirely possible that solutions worked out for some of the difficulties on these tiny islands may point the way toward means of solving the infinitely more complex and vitally important conservation problems today facing the world. An ecological equilibrium between these island peoples and their limited environments is a necessity if they are to survive without continued outside assistance. A similar equilibrium must be established between the human race and its more and more limited world-environment, a problem the failure to solve which will have consequences that may not be mitigated by any outside assistance. Hence the working out of the programme developed for Micronesia may well be watched with the keenest interest by those concerned with conservation in the rest of the world.

The little available evidence indicates that prior to the advent of Europeans in the Pacific, the Micronesians had established an equilibrium with their environment. Occupation by four successive alien authorities, Spanish, German, Japanese, and American, profoundly disturbed this equilibrium in many ways. Important among these were punitive wars against stubborn natives, the introduction of commerce, foreign diseases, and foreign agricultural practices, crops, and pests, the curbing of local wars, colonization and resulting plantation agriculture, and finally the Second World War and its consequences. The net effects upon the ratio between the population and the capacity of the environment to support it have varied from time to time and in different islands. The overall results in those islands having the greatest contact with outside influences have undoubtedly been serious inroads on resources of all sorts, especially soil and timber. Early trends toward falling off of native populations have largely been curbed by modern medical services and instruction in hygiene. In local areas such as Yap a falling off in population still continues, but in the region as a whole definitely the opposite is the case. A disturbing portent for the future is contained in the report of the Naval Administration (to October 1, 1948) (p. 2) of a birth rate of 33·11 per thousand compared with a death rate of 17·19 per thousand. In the same report is the statement that "If the Navy's Health Services Policy is continued . . . hospitalization facilities . . . may be reduced because it is believed the need for them will diminish as time goes on". There is no question that this is a desirable trend. Health among a population is basic to all other progress. However, a birth rate almost twice as high as the death rate inevitably presents a problem in conservation. Although the population a hundred and fifty years ago is estimated (Navy Adm. Rept. p. 21) at three times the present number, and although there is doubtless room for more people than the present figure of 51,475, it must be remembered that the natural resources of the islands have diminished, and that the standard of living that is being introduced will require greater resources per capita than were needed for the primitive standard of a century and a half ago. The parallel between this situation and that in the world as a whole is obvious.

Soil erosion problems in the western Carolines and Marianas are aggravated by the seasonally dry climate, and the pernicious practice of burning. The habit of planting on steep slopes makes this worse, but it is not particularly widespread at present, with a relatively low population. An increase in population will doubtless bring with it the same destruction of soil and water supplies that is so evident in many of the more thickly settled parts of the tropics.

Still another aspect in which difficulties confronting the world are reflected in miniature is that of the disappearance of plants and animals, both wild species and local varieties of domesticated ones. Scarcely a beginning has been made in the study of these insular floras and faunas. We know little of what we can learn from them, either scientifically or practically, and they are disappearing rapidly. Some forms are already extinct, probably more than we realize. Varieties of cultivated economic plants, evolved in this area literally by hundreds, are valuable sources of genetic material. Once lost they can never be replaced. Yet their preservation for future use depends on the whims of native cultivation. Fortunately many are trees, and will not disappear too rapidly. But new introductions tend to displace the old local ones with surprising ease. And despite changing cultural patterns, these native economic plants, coconuts, breadfruits, bananas, yams, taros, and others, are certain to remain the basis of native economy. In view of the rising population it is essential not to lose any potential chance of increasing agricultural productivity. Improvement of varieties or breeding for disease-resistance is dependent on preservation of these gene-reservoirs.

All of these problems and many more, such as public apathy and lack of understanding, official short-sightedness, individual greed, and expediency, which face the world conservationists are here displayed on a reduced scale. Thus any conservation programme that may be tried out in Micronesia may be regarded as a "pilot operation" to guide larger ones elsewhere. Therefore the plans for this programme are a matter of more than general interest. Perhaps, also, they may be of special interest to other nations with similar conservation problems in their own trusteeship areas.

The recommendations forming the substance of the programme are contained in a report entitled "Conservation in Micronesia" compiled by Harold J. Coolidge and published in 1948 by the National Research Council. This contains the results of the Honolulu and Washington conferences, with some of the papers and background materials forming the basis of the discussions. The general programme recommended is as follows:

All policies should be directed toward limiting the population to numbers compatible with the maintenance of high standards of health, nutrition, sanitation, and with a permanent economy based on the actual carrying capacity of the land and the extent of the renewable natural resources of the archipelagoes. Immigration from outside parts of the world should be severely limited or prohibited.

A conservation officer should be made a part of the framework of the administration of the Trust Territory and an advisory committee on conservation in Micronesia should be set up for assistance to the authorities in matters affecting conservation. It is a pleasure to be able to report that this officer is being appointed and that the committee has been set up and has held its first meeting.

A permanent data-collecting service should be established. This is, of course, basic to the intelligent functioning of any such programme.

Overgrazing, excessive use of fire, and other destructive agricultural practices should be controlled, introduction of exotic plants and animals strictly regulated, and efforts made to eliminate those already established if they are detrimental.

Measures should be taken to preserve the native forests and to protect native animals and migratory birds. Certain areas should be set aside as reserves for the protection of native fauna and flora, as watershed protection, and to preserve interesting historical and archaeological sites for future study and enjoyment. A list of the most important such areas is provided, and it is suggested that a special commission may be undertaken when the conservation officer is established in the area and has had a chance to size up the problems on which he needs assistance.

It is recognized that those to benefit most, ultimately, from a conservation policy will be the natives, and that the effectiveness of such a policy is dependent on their understanding of and co-operation with it. Therefore such aspects of it as will increase their food supply and better their general welfare should be stressed. Their own habits and customs should be studied with a view of encouraging those operating for conservation and discouraging or changing those with detrimental effects. Above all, educational programmes should be aligned to harmonize in every way with conservation objectives and to develop habits of thinking and action compatible with these aims. An understanding of the principles and objectives of conservation should be one of the basic results of all educational policies, on the higher levels of training of officials and teachers, as well as on the level of public instruction. Enforcement of conservation regulations should be the responsibility of local officials and governing bodies wherever possible.

It is of the utmost importance that this programme be kept flexible and adaptable to changes in conditions, unforeseen developments, and better understanding resulting from experience and an increasing body of basic information. This will largely be the responsibility of the advisory committee. This committee, composed of two panels, one in Washington, D.C., the other in Honolulu, has been chosen to contain a wide range of specialists with many fields of knowledge represented, both on the area and people concerned as well as on the principles of conservation. It is intended that the committee work in the closest possible co-operation with the conservation officer, and that he will feel free to call upon them for advice and backing whenever necessary to develop and implement the programme envisioned for the preservation of a richly habitable and satisfying environment for the permanent enjoyment of future generations of Micronesians. It is only in this way that this small but interesting and worth-while people may be enabled to make their contribution to the culture of the world.

SAVE-THE-REDWOODS

By WALLACE W. ATWOOD, Clark University

[*Abstract*]

THIRTY years ago a league was organized for the special purpose of preserving as many as possible of the magnificent giant trees, *Sequoia sempervirens*, of the California coastal area. These trees range up to 3,000 years in age and several of them reach to 350 feet in height. Their cathedral arches through which the sunlight filters provide most inspiring vistas to all who wander through these wonderful groves.

Millions of dollars have been made available to the league from private and from California State funds for the purchase from private owners, chiefly lumber companies, of many of the choicest redwood groves. Organizations, such as the Garden Clubs of America, have contributed generously. Several memorial groves have been set aside for individuals who have been promoters of this movement.

During 1947 over 300,000 dollars were contributed for the purchase of additional redwood groves. One grove is to be a memorial to the veterans of the World Wars, and another is to be set aside in honour of the late Madison Grant, one of the founders of the league. Whatever financial aid the league contributes is matched by a similar contribution from the State of California. After the purchase of these forested areas they are turned over to the California State Forest Reserves for permanent ownership and care. During 1947 two thousand and seven acres of redwood forest were set aside for permanent preservation.

For a time we had a fund of five million dollars contributed by an individual from which we drew enough to double any contribution secured by the league from other sources. With the doubling by the State of California this meant that each dollar contributed represented four dollars.

The discovery by Dr. Ralph Cheney of the University of California during the past year of the ancestral cousins of these beautiful trees, known as *Metasequoia* in the far interior of south-west China, is of special interest. Previously Dr. Cheney had shown from fossil remains that during Tertiary time the redwoods had migrated southward from Alaska into California.

Sequoia sempervirens are known nowhere in the world except on the California coast where geographical conditions, especially the mild temperatures and the fogs from the Pacific Ocean, are favourable for

their growth. They can, however, with proper care, be raised in other places. They are a choice heritage and should be preserved for all time for all the people of the world to enjoy.

PACIFIC CONSERVATION PROBLEMS

MESURES DE CONSERVATION A PRENDRE POUR LA SAUVEGARDE DE LA FLORE DE LA NOUVELLE-CALEDONIE

Par A. Guillaumin, Muséum National d'Histoire Naturelle, Paris

[*Résumé*]

Les races primitives ont détruit la flore naturelle en créant des espaces libres pour leurs cultures vivrières extensives et leurs troupeaux ont devaste les arbustes et les arbres, mais, dans bien des endroits, il s'est cependant établi une sorte d'equilibre entre l'homme, ses animaux domestiques et les plantes.

Les races dites civilisées, les Blancs surtout, en raison des besoins sans cesse grandissants, sont devenues une terrible menace pour la flore naturelle.

Certaines espèces vegétales sont tres etroitement localisées ou ne sont representées que par un très petit nombre d'individus se régénerant peu ou pas. Ce sont justement des essences forestières présentant des bois de grande valeur. Les exploitants forestiers abattent fréquemment des arbres n'ayant pas encore atteint leur complet développement plutôt que de rechercher plus loin des sujets bons à abattre, car on sait qu'en pays chauds il est rare de rencontrer des peuplements purs d'une même espèce ou composés d'un petit nombre d'espèces.

En Nouvelle-Caledonie c'est le cas, notamment dans la region de Prony et de la Plaine des Lacs, du *Spermolepis gummifera* Brong. et Gris, le Chêne-gomme, de beaucoup de Conifères, en particulier des *Agathis* ou Kaoris et *Callitropis araucarioides* Compton, localise dans l'extrême-sud de la Grande Terre.

Si l'*Araucaria Cookii* R.Br., du moins dans sa forme littorale de Pin colonnaire, est abondant sur le pourtour de la Grande Terre et les ilots voisins (c'est a lui que l'ilot Porc-Epic doit son nom), à l'ile des Pins il n'en existe plus que deux peuplements, l'un sur le littoral N.E. a Oro, l'autre, à l'ile Alemene (c'est du reste pour cela que les navigateurs indigènes l'eppellent l'Ile Brosse).

Il est de toute urgence de règlementer l'abatage et de creer des reserves naturelles intégrales, mais il ne s'agit pas seulement d'edicter des règlements, il faut surtout les faire appliquer et, pour cela, seule une surveillance effective le permet.

Inutile de rappeler qu'il y aurait lieu de proteger aussi le *Santalum austrocaledonicum* Vieill. qui a ete pillé avant l'occupation française.

PROTECTION DE LA NATURE EN NOUVELLE-CALEDONIE

Par René L. A. Catala, Institut Français d'Océanie, Noumea

La Nouvelle-Caledonie est surtout considerée sous son aspect de territoire très riche en minerais (nickel et chrome en particulier) et l'intérêt qui est porte à ces éléments de base autour desquels gravitent la majorité des activités humaines de cette Ile, a fait négliger souvent, non seulement d'autres facteurs économiques mais aussi l'étude d'un grand nombre de problèmes se rattachant, de près ou de loin à ces activités.

La Protection de la Nature est de ceux-là.

De timides projets ont bien vu le jour depuis une dizaine d'années tant en ce qui concerne la protection de la forêt que celle des richesses marines mais, en dehors de certaines interdictions comme celle de la coupe de bois précieux et rares tels que le *Calitropsis* ou celle ayant trait à la pêche du trocas (*Trochus niloticus*) et où les infractions sont faciles à contrôler, aucune politique réelle de sauvegarde n'a été suivie. Aussi peut-on dire que, pratiquement, en Nouvelle-Calédonie et dans les îles voisines tout est à créer dans ce domaine.

Avant d'aborder l'étude précise des problèmes les plus urgents ou les plus importants, il convient de brosser un rapide tableau de ce que représente cette île de 400 kilomètres de long sur une largeur moyenne de 50 k., orientée Sud-Est Nord-Ouest et qui, à l'Est de l'Australie est comprise entre le 20ème et le 22ème degré de latitude Sud et entre le 161ème et le 167ème degré de longitude.

Cette crête montagneuse à relief accusé avec des sommets de 1600 métres présente un versant oriental assez abrupt avec une grand proximité des crêtes et du littoral où la mer baigne parfois la base même de quelques montagnes, tandis que le versant occidental montre une déclivité plus douce et une importance beaucoup plus grande des régions basses.

Les rivières et ruisseaux, très nombreux, ont un débit fort irrégulier et, sauf le Diahot, la plus importante rivière calédonienne qui coule au Nord de l'Ile, ces cours d'eau ne sont, en général, que de faible longueur.

Une ceinture de récifs barrière entoure l'île et crée un lagon plus ou moins large, semé d'îlots et de récifs frangeants.

Le climat de la Nouvelle-Calédonie rentre dans la catégorie "climat méditerranéen chaud", c'est le climat marin type qui vaut à l'île d'être bien favorisée quant aux précipitations atmosphériques. L'ensemble de facteurs qu'il conditionne entraîne divers faciès végétaux qui peuvent se classer brièvement en :

Zone littorale,
Savane herbeuse,
Galerie forestière inférieure,
Galerie forestière supérieure,
Forêt humide des contreforts,
Forêt sèche,
Maquis des sommets.

Quatre plantes qui, en dehors des formations primitives occupent de très grandes surfaces, méritent une mention spéciale. Ce sont :

Le Niaouli (*Melaleuca viridiflora*),
Le Goyavier (*Psidium goava*),
Le Lantana (*Lantana camara*),
Le Lantoro (*Leucena glauca*).

Le Niaouli, endémique à la Nouvelle-Calédonie, étend un peu plus chaque année son aire de dispersion. Son extension est un signe de rupture d'équilibre en même temps qu'une conséquence de ce déséquilibre à la suite de l'intervention d'un facteur extérieur qui est le feu.

Cet arbre qui résiste victorieusement à l'action des flammes, prend la place des plantes que le feu à détruites. Son action sur les sols où il s'installe est nettement stérilisante et le fait que la strate herbacée sous *Melaleuca* est une strate à graminées qui brûle parfaitement, facilite encore cette stérilisation.

Par contre, la dégradation par ravinement des sols en pente est retardée ou empêchée par le fait que le *Melaleuca* vient colmater rapidement les brèches faîtes par le feu dans les peuplements primitifs.

Le Goyavier ne croît pas sous le couvert des *Melaleuca,* mais s'est répandu ailleurs, intensément comme aussi le lantana, plante introduite et qui est aujourd'hui étroitement intégrée à certains faciés végétaux.

Par contre le *Leucena* joue un rôle aussi utile que celui des deux plantes précédentes est néfaste.

Puissant régénérateur du sol il est en même temps un facteur de fixation des sols et d'enrichissement des terres.

Influence du facteur humain sur les faciès végétaux de l'Ile.

Les traces sont multiples au flanc des montagnes et des collines, des anciennes terrasses où les canaques faisaient croître le taro (*Colocasia esculenta*).

L'alimentation en eau de ces terrasses nécessitait un système d'irrigation considérable et les travaux de soutènement que ce système impliquait réprésentait un élément de valeur contre l'érosion par ravinement puisque le continuel entretien qu'il exigeait évitait le glissement des terres en même temps qu'il apportait un facteur de régularisation.

Ce réseau de canalisation a disparu à peu près complètement tant à cause de la dispersion des tribus indigènes que l'accroissement rapide du cheptel importé, troupeaux de boeufs d'abord, hardes de cerfs ensuite.

A l'abandon d'un tel système sont venus s'ajouter d'autres éléments perturbateurs dont le plus grave a été le feu.

En Nouelle-Calédonie, comme partout ailleurs, le primitif ne s'astreint point à des défrichements laborieux et proportionnels aux surfaces à mettre réellement en valeur et c'est au feu qu'il a recours tant pour ses cultures ancestrales que pour les nouvelles telles que le café par exemple. Aucune précaution n'est prise, (attente d'un temps calme ou contre-feux préalables) et les incendies allumés prennent alors des proportions considérables. D'où stérilisation du sol et morsures de plus en plus profondes dans les lisières de forêt primaire avec, en conséquence, la formation de types de végétation secondaire.

De son côté la culture des blancs a apporté des modifications incontestables aux faciès anciens. Si la création des caféières sous ombrage planté s'est faite le plus souvent au détriment de la galerie forestière inférieure, elle a eu cependant, grâce à la présence des légumineuses arborescentes qui maintiennent le sol en place, moins de fâcheuses conséquences que les cultures annuelles faites sur des terres de bord de rivière. Celle-ci, formées au cours des âges par les inondations successives gardent leur caractère d'instabilité qui se traduit par des arrachements souvent considérable surtout quand les crues agissent sur des labours fraîchement exécutés.

Ces modifications profondes ne font que s'accentuer au fur et à mesure qu'augmente la destruction des éléments forestiers primaires qui commandent le régime des eaux et le régularise.

D'autre part, la nécessité pour les éleveurs, de rajeunir les pâturages et, pour les agriculteurs, d'opérer le nettoyage rapide des sols à mettre en valeur conduit les uns et les autres à user du moyen simple et économique qu'est l'incendie.

Malheureusement ces feux gagnent souvent les zones forestières.

On estime ne général que les forêts du Sud sont beaucoup plus atteintes par les feux que celles du Nord et du Centre de l'Ile et on explique cette vulnérabilité par la présence dans les forêts couvrant les sols serpentineux de ces régions méridionales, d'un pourcentage très élevé d'essences à résine et à gomme qui leur confèrent un haut degré de combustibilité, tandis que les forêts humides en raison de l'hygrométrie intense qu'elles conditionnent sont beaucoup moins vulnérables.

Ces dernières sont pourtant atteintes et l'action des feux de brousse sur leurs lisières s'y traduit par des pertes annuelles sérieuses mais dont il est impossible de chiffrer l'importance, même approximative.

Feux de brousse, déboisements par exploitation abusive ou plus exactement mal conduite, "grattages" d'exploitations minières s'ajoutent à un relief très tourmenté pour accélérer le processus de dégradation par l'érosion et surtout érosion par ravinement et lessivage des terres. C'est le drame des pays accidentés.

Les remédes à employer pour limiter l'extension des dégâts sont, à mon avis, de trois ordres :

1 — Une réglementation forestière très précise;
2 — La constitution de réserves à définir aussitôt que possible;
3 — Une politique d'éducation du public.

1—Récement élaborée par un Officer des Eaux et Forêts du cadre général, cette réglementation est aujourd'hui établie et porte principalement sur les terrains à livrer à la colonisation, terrains actuellement domaniaux et dont il importe de distraire les surfaces n'ayant aucun intérêt agricole ou pastoral et qui portent des blocs forestiers que leur situation ou leurs caractères devraient rendre inaliènables.

Cette réglementation visant surtout les terres avec forêts a prévu le mode d'attribution de permis de coupes où tout exploitant sera soumis aux habituelles conditions portant sur la surface réelle à exploiter, le diamètre des arbres, la durée du permis etc. . . toute infraction à ces obligations étant une cause de déchéance qu'une procédure de retrait entraînera.

Ce n'est que peu à peu, au fur et à mesure du classement des forêts— qui sera en même temps un inventaire — que pourront être déterminés les peuplements à désigner comme forêts protégées soit au titre de réserves d'intérêt économique soit à celui de réserves spéciales, soit enfin au titre de réserves intégrales.

On s'étonnera peut-être que je n'aie point envisagé la question de reboisement mais la rareté de la main-d'oeuvre en Nouvelle-Calédonie le rend pratiquement impossible sur une échelle assez vaste pour qu'il soit efficace. Cette impossibilité est fort regrettable car un effort de reboisement aurait pu limiter l'érosion sur les pentes fortes, dans les bassins de réception des rivières et sur les berges des cours d'eau.

2 – C'est donc la forêt encore existante qu'il faut sauver, et le point le plus important est la création de réserves sur les crêtes et les pentes les plus déclives de certaines montagnes, dans les blocs forestiers qui ont une valeur de chateaux d'eau.

Ce plan de conservation semble devoir s'orienter beaucoup plus vers une protection intensive – je veux dire sur des surfaces données, même si elles sont faibles – plutôt que vers une politique de protection extensive, cherchant à sauvegarder telle plante ou tel animal sur toute l'étendue du territoire, solution irréalisable dans un pays où les moyens de surveillance effective sont impossibles à mettre en oeuvre faute de personnel suffisant en nombre et en compétence. En résumé, la première tâche qui s'imposait consistait à préciser les emplacements et à les définir dans leur étendue et leurs objets, la seconde, beaucoup plus ardue, devra porter sur l'organisation d'un contrôle effectif.

3 – Mais quelles que soient les méthodes employées, les conditions de fonctionnement de l'organisation de surveillance et les modalités d'application des arrêtés qui auront été pris, le problème de base, dans un pays où la protection de la nature est entièrement à créer est un problème d'ordre psychologique.

On s'accorde généralement à reconnaitre que la mise en oeuvre d'un programme de sauvegarde et de conservation est d'une exécution difficile parcequ'il est malaisé de faire accepter des contraintes lorsqu'elles se heurtent à des intérêts puissants ou simplement à des habitudes locales très anciennes.

En réalité le mépris du public pour des interdictions ou des restrictions et les mécontentements – voir même les oppositions qu'ils font parfois surgirtiennent le plus souvent à une incompréhension des relations de causes à effets entre les mesures préconisées et leurs répercussions lointaines.

Aussi est-il indispensable que, parallèlement à un programme de réglementation, une adroite propagande soit entreprise. La radio, le cinéma, la presse, des conférences doivent peu à peu amener le public à comprendre que la mise en réserve de telle ou telle région ou que le fait d'exclure temporairement ou définitivement tel ou tel périmetre forestier des possibilités d'exploitation ne sont pas un luxe ou une fantaisie destinée à satisfaire les intérêts intellectuels de quelques savants mais une nécessité vitale pour la collectivité toute entière et pour le bien-être des générations à venir. Et ceci vaut autant pour la protection des bios terrestres que pour celle des bios marins.

Les pays dotés de centres culturels possèdent des moyens puissants qui leur permettent de jouer ce rôle éducatif, et beaucoup l'ont fait.

En Nouvelle-Calédonie, le jeune Institut Français d'Océanie peut, lui aussi, concourir à cette oeuvre.

C'est un grand devoir en effet pour les chefs des diverses disciplines qui y sont représentées de faire comprendre au public avec lequel ils sont en contact les grands problèmes de conservation en même temps qu'ils peuvent trouver de fréquentes occasions d'être les conseillers techniques des services administratifs.

Si le pédologue a, dans un tel organisms, un rôle prépondérant à jouer en face des problèmes de conservations parcequ'il possède tous les éléments lui permettant une propagande de vulgarisation de la science du sol, les autres spécialistes sont, eux aussi, en mesure d'apporter leur contribution à un tel effort. En étudiant flore ou faune du pays qu'ils prospectent ils sont mieux à même que quiconque, au fur et à mesure qu'ils en font l'inventaire d'attirer l'attention sur tel ou tel élément susceptible de justifier des mesures de protection. L'Ethnologue lui-même se trouve être dans des conditions remarquables de propagande au sein des tribus indigènes dont il étudie les caractères et chez lesquelles il tentera d'imposer le respect de l'arbre.

Nul doute que la foi et l'enthousiasme de ces hommes ne soient un sûr garant de réussite.

RAPPORT SUR LA PROTECTION DES OISEAUX SAUVAGES DANS LES ILES FRANCAISES DE L'OCEANIE

Par M. J. Berlioz, Muséum National d'Histoire Naturelle, Paris

Le domaine d'influence française en Océanie, pour n'être pas des plus considérable, touche pourtant à des zones variées de cette partie du monde : il comporte en effet un certain nombre d'îles en Mélanésie (Nouvelle-Calédonie, Iles Loyauté, Nouvelles-Hébrides), et d'autres en Polynésie orientale (Iles de la Société, Touamotou, Marquises, etc.). L'évolution actuelle de la faune, celle-ci étant apparentée plus ou moins étroitement à celle des domaines insulaires voisins, y subit pratiquement les mêmes vicissitudes que dans ceux-ci et, dans l'ensemble, l'expérience acquise pour les uns peut s'appliquer également aux autres.

Il est indéniable que, dans la menace générale qui pèse actuellement sur les éléments de la nature dans le monde entier, toutes les îles, et plus particulièrement celles de dimensions restreintes dans la zone tropicale (c'est précisément le cas des îles précitées), sont encore les points les plus directement et les plus sévèrement menacés. Les populations d'Oiseaux elles-mêmes, qui, dans l'évolution des Continents, montrent, grâce à leurs facultés d'adaptation et de déplacement rapides, tant de possibilités d'écarter les menaces de destruction qui guettent la plupart des autres types animaux, n'y peuvent le plus souvent—à l'exception des grands voiliers et des Oiseaux de mer—échapper à ces vicissitudes, l'exiguité et l'isolement de tels territories ne leur permettant guère de transposition spontanée de leur habitat.

Au cours des 17e et 18e siècles, les Antilles et les Mascareignes ont été ainsi dépouillées déjà par la colonisation d'une partie de leurs éléments fauniques autochtones, en particulier d'un bon nombre d'espèces d'Oiseaux. Dès la seconde moitié du 19e siècle, ce fut au tour des îles de l'Océanie de subir le même sort. L'ignorance où l'on était des conditions d'équilibre de la nature dans ces îles, l'utilisation intensive de certaines espèces d'Oiseaux dans l'alimentation des colons, et les déprédations que d'autres espèces ont été accusées de commettre au détriment des cultures, pouvaient être considérées comme les excuses originelles d'une telle régression. Depuis lors, malheureusement, les facteurs humains susceptibles d'accélérer cette décadence, indépendamment des facteurs naturels, n'ont fait que se multiplier.

A l'heure actuelle, les causes principales, d'origine humaine, déterminant la régression des espèces d'Oiseaux sauvages dans les îles océaniennes se sont révélées les suivantes :

(1) destruction directe par la chasse ou le dénichage, dans des buts alimentaires, industriels ou commerciaux;

(2) captures trop nombreuses d'Oiseaux vivants en vue du commerce des Oiseaux de cage ou de volière, pour le maintien en captivité;

(3) transformation, volontaire ou accidentelle, des biotopes naturels, ce qui prive rapidement ou progressivement les Oiseaux de leurs conditions normales de nidification et d'alimentation;

(4) usage plus ou moins généralisé du feu dans cette transformation : c'est une des calamités les plue néfastes pour la petite faune des taillis et des savanes;

(5) introduction par l'homme d'animaux domestiques, tels que chiens, chats, cochons, qui peuvent se montrer très destructeurs pour l'avifaune autochtone, au moins pour les espèces nichant à terre;

(6) introduction et acclimatation à l'état sauvage d'animaux susceptibles de nuire à l'équilibre naturel des espèces autochtones, qui peuvent être supplantées même par certains Oiseaux étrangers, inoffensifs en apparence, mais plus prolifiques;

(7) enfin missions de recherches scientifiques insuffisamment contrôlées, qui font trop souvent des prélèvements numériques exagérés parmi des populations d'Oiseaux déjà appauvries.

Depuis ce dernier demi-siècle, un contrôle administratif plus serré a permis d'établir, non seulement dans les territoires français mais également dans toutes les autres îles, sans en excepter les plus considérables telles que l'Australie et la Nouvelle-Zélande, le rôle effectif de ces diverses branches de l'activité humaine—rôle d'autant plus dangereux qu'elles s'exercent le plus souvent parallèlement ou simultanément les unes et les autres.

Les types d'Oiseaux qui se montrent particulièrement frappés dans leur prospérité sont, en raison de la diversité même de ces facteurs de destruction, aussi nombreux que variés. A citer surtout :

(1) les grandes colonies d'Oiseaux marins, qui fournissent les unes un lourd tribut à l'industrie des matières grasses (tels les Pétrels de la région australienne), d'autres (telles les Sternes) à l'exploitation commerciale des oeufs.

(2) Les Oiseaux vivant au sol, ne possèdant aucun moyen de défense naturel, et surtout ceux dont la reproduction est très limitée. Tel le Kagou, de Nouvelle-Calédonie, où, selon les plus récentes appréciations des voyageurs contemporains, son existence reste trés menacée du fait surtout des animaux domestiques, après l'avoir été aussi par de trop ardentes recherches en vue d'en capturer des spécimens vivants: or la reproduction de cet Oiseau est limitée à un seul oeuf par couvée. Telles encore diverses espèces de Rallidés, ne possèdant qu'une puissance voilière faible ou nulle, et souvent étroitement localisées dans certaines îles.

(3) Les Pigeons, Oiseaux souvent recherchés pour l'alimentation, surtout dans les îles de l'Océanie, où les Pigeons frugivores, du groupe des Treronidés (*Ducula, Ptilinopus,* etc.), connus aussi sous le nom de "Pigeons verts", constituent précisément à la fois un élément important de l'avifaune autochtone et un gibier fort apprécié. La reproduction des espèces de ce groupe, limitée elle aussi à un oeuf par couvée, rend leur exploitation comme gibier dangereuse pour leur prospérité. A signaler entre autres à ce sujet le "Notou" de Nouvelle-Calédonie

(*Ducula goliath*) et les divers Ptilopes répandus dans tous les Archipels. Quant aux espèces terrestres de Pigeons, telles les *Gallicolumba* de Polynésie orientale, elles ont surtout à redouter, comme tous les Oiseaux du même biotope, le contact des Mammifères domestiques introduits : l'exemple du *Didunculus*, ce type de Pigeon si remarquable des Iles Samoa et si raréfié à l'heure actuelle, doit retenir l'attention.

(4) Les Perroquets, autre groupe d'Oiseaux abondamment représenté autrefois dans toutes les îles de l'Océanie et qui, plus encore que le précédent, se montre toujours un des plus dangereusement affectés par la colonisation, mais pour d'autres raisons : la nocuité que les colons attribuent à certaines espèces vis-à-vis des cultures et qui les fait massacrer sans pitié (la tendance de ces Oiseaux à se familiariser au contact de l'humanité accroît encore le danger à cet égard) et l'exploitation intensive que l'on en fait comme Oiseaux de cage. Il faut y ajouter aussi les habitudes nidificatrices des Perroquets, qui utilisent essentiellement les cavités d'arbres élevés, en forêt, et souffrent ainsi un préjudice particulièrement sensible du fait de la déforestation.

(5) Enfin les petits Passereaux, qui, en général, ont beaucoup moins à pâtir directement des entreprises humaines que les types d'Oiseaux précédents, sont par contre fréquement victimes des introductions d'Oiseaux étrangers, ceux-ci contribuant à leur tour soit à les détruire directement, soit à leur nuire par l'accaparement des ressources alimentaires naturelles ou des lieux propices à la nidification. L'exemple, récement mis en lumière, du Corbeau de Nouelle-Calédonie (*Corvus moneduloides*) introduit aux Iles Loyauté, où il est si préjudiciable aux petits Passereaux autochtones (surtout *Zosterops*), montre les inconvénients de telles entreprises. De même le cas du Martin triste de l'Inde (*Acridotheres tristis*), acclimaté en Nouvelle-Calédonie, comme il l'a été aux Mascareignes, à Madagascar, et en bien d'autres points encore, et dont les services rendus comme destructeur d'insectes nuisibles compensent insuffisamment les préjudices causés dans la prospérité des Passereaux indigènes.

Il ne faut pas oublier que, primitivement, la faune autochtone de l'Océanie, à l'est du moins des grandes terres néo-guinéenne et australienne, était complètement dépourvue de toute espèce de Mammifère prédateur susceptible de nuire à la vie des Oiseaux et que quelques Oiseaux de proie — absents même en Polynésie orientale — étaient à peu près les seuls éléments régulateurs naturels de l'équilibre avifaunique. On conçoit que, dans ces conditions, cette avifaune ait pu maintenir une prospérité numérique suffisante, même avec une prolificité médiocre. Mais, si, d'après l'opinion des auteurs anciens, certaines espèces paraissent même n'avoir jamais été vraiment abondantes, il n'est que trop fatal que les effets de la colonisation aient été aussi rapidement désastreux pour un équilibre en somme déjà fragile.

A l'heure actuelle, l'île de Tahiti par exemple passe pour être dépouillée de presque tous les éléments de son avifaune primitive, éléments qui ont d'ailleurs été remplacés artificiellement, non sans quelque imprudence, par des importations et des acclimatations en liberté d'Oiseaux étrangers, tels que des Plocéidés d'Afrique et autres Passereaux. Entre autres, les si charmantes espèces de Perruches indigènes, le Coriphile (*Vini peruvianus*) et les *Cyanorhamphus* y semblent complètement éteintes, bien que la première tout au moins existe encore en quelque abondance dans de petites îles voisines.

Contre ces dangers on doit proposer un certain nombre de remèdes, dont l'application partielle qui en a été faite en ces dernières années — depuis que la nécessité de protéger la nature a été appuyée par une législation appropriée — a d'ailleurs montré l'efficacité (par exemple la protection absolue de la Perruche d'Ouvéa, qui semble maintenant plutôt en voie de progression). Ces remèdes sont les suivants :

— 1°. tout d'abord la création de "réserves de la nature", c'est-à-dire de territoires strictement à l'abri de toute exploitation humaine, sur des superficies assez étendues, les réserves trop restreintes n'ayant qu'une efficacité médiocre, lorsqu'il s'agit de Vertébrés à sang chaud.

— 2°. Le renforcement et l'application très stricte de la législation cynégétique, concernant la chasse et la capture des Oiseaux gibiers, en particulier des Pigeons frugivores ou Pigeons verts.

— 3°. Le contrôle limitatif de la capture des Oiseaux vivants, ainsi que des récoltes des missions scientifiques et de tout essai d'acclimatation à l'état sauvage d'animaux étrangers.

— 4°. La surveillance plus étroite des animaux domestiques dangereux pour l'avifaune (Chiens, Chats, Cochons), et l'urage de sanctions pour leurs méfaits.

— 5°: La protection absolue (soit définitive, soit temporaire, selon l'état de prospérité dûment constaté de l'espèce en question) de quelques espèces d'Oiseaux particulièrement appauvries et menacées. Cinq au moins me paraissent actuellement devoir faire l'objet de cette mesure :

le Kagou (*Rhinochetus jubatus*), en Nouvelle-Calédonie;
la Perruche cornue de Nouvelle-Calédonie (*Eunymphicus cornutus*);
la Perruche cornue de l'île Ouvéa (*Eunymphicus uveaensis*);
le Coriphile ou Perruche de Tahiti (*Vini peruvianus*);
le Coriphile ou Perruche des îles Marquises (*Vini ultramarinus*);

auxquelles il conviendrait d'ajouter, pour les îsles de Polynésie orientale, toute autre espèce de Perruche (*Cyanorhamphus*), s'il en existe peut-être encore quelques spécimens?

— 6°. Le transfert artificiel, par les soins de services techniques compétents, de spécimens des espèces les plus menacées en des îles inhabitées, qui peuvent être pour ces survivants des refuges inviolables et par conséquent leur offrir des possibilités de régénération, peut être envisagé aussi éventuellement comme un secours efficace (il a d'ailleurs été pratiqué, dit-on, avec succès pour la Perruche de Tahiti). Mais cette méthode risque de provoquer quelque dégénérescence ou quelque altération dans les caractères primitifs de l'Oiseau.

— 7°. Enfin la régénération artificielle, en captivité, peut également intervenir avec succès, mais comme un pis-aller ou du moins comme un moyen connexe de la protection naturelle de l'espèce, pour hâter sa multiplication — car certains Oiseaux (ce fut le cas, par exemple, du Pigeon rose de l'île Maurice, *Nesaenas mayeri*) se montrent absolument rebelles à de telles tentatives.

A la multiplicité des facteurs de destruction et de raréfaction cités ci-dessus, il convient en effet d'opposer la mise en action simultanée

de plusieurs méthodes capables d'enrayer la décadence des espèces aviennes — ces méthodes restant d'ailleurs subordonnées au contrôle et aux décisions des autorités locales compétentes et responsables. Celles-ci auront donc le devoir de fixer l'opportunité de telles mesures et de choisir, selon les conditions législatives et sociales en vigueur, les modalités d'application les plus appropriées.

Ce n'est que grâce à de mesures de cet ordre, strictement appliquées, que l'on peut espérer maintenir un équilibre durable parmi les populations d'Oiseaux indigènes dans les îles françaises de l'Océanie. Pour ces îles, en comparaison surtout de leur grande indigence en autres vertébrés aériens, la faune avienne constitue en effet un patrimoine naturel des plus précieux, qu'il est urgent de protéger.

PHILIPPINE WILDLIFE PROBLEMS

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Wildlife was one of the few phases of Philippine economy apparently favoured by the last war. The policy of the Imperial Japanese army of occupation of confiscating firearms, and commandeering motor vehicles, obviously affected favourably the restoration of wildlife which was in a seriously depleted condition before the outbreak of the war. However, cessation of hostilities resulted in an enormous surplus of United States army vehicles and firearms. This coupled with post-war Filipinos' desire to avenge, aggravated by lack of government supervision, proved very detrimental to Philippine wildlife. This includes myriads of migratory game birds that visit the Philippines yearly. These unfortunate creatures, awaited by destruction in all the lands they visit, and especially because in many cases they do not get protection in the nearby countries, are fast vanishing; and unless an understanding is reached by countries many of which are represented in this Congress, it will not be long before these birds are but memories of the past.

It is the object of this paper to present the conditions obtaining as regards Philippine wildlife (birds and mammals) and to appeal for co-ordinated action among south-western Pacific countries annually visited by migratory birds, in order to preserve them for posterity.

The birds and mammals reported in this paper are some of the important forms of wildlife observed to be reduced considerably. Due to lack of facilities for record taking, the information presented in this paper has been secured mostly from hunters, and by personal observation.

Migratory Birds

The geographical location of the Philippines is such that many migratory birds have been recorded. However, their origin, destination, migratory routes and other problems have not been definitely ascertained due to lack of systematic studies along this line. Here is one of the many phases of wildlife conservation in this part of the world where understanding and co-operation of neighbour countries are necessary.

Migratory Game Girds

Shore birds:—The birds that migrate to the Philippines are, for purposes of this paper, grouped into game and non-game. Shore birds represent the majority of the visiting game birds. A total of 45 forms have been recorded in the Philippines. These include plovers, lapwings, curlews, godwits, sandpipers, tattlers, stints, snipes, stilts, avocets, etc. These birds begin to arrive in the island of Luzon about the middle of August. They reach their peak of greatest abundance about the third week in September. The open season for shore birds starts September 1, and ends the following December 31. Although no actual marking of the birds has been done, observation shows that many, if not all, of the birds are transients moving away after a short rest. The short period of residence probably accounts for the hunters opening fire on them upon arrival, before the authorized opening date for the hunting season and without giving them a chance to rest after their long flight. As a result of this practice, shore birds shot during the early part of the season have less flesh than those killed later. The people's lack of interest in conserving game birds is further manifest in their night trapping of new arrivals, using lights and nets. The result of their activities can be seen the following morning when pedlars of live birds are a common sight along highways and public markets. Some of those close to Manila sell their birds in the city. This practice of selling live birds is also expressly prohibited in the local game law.

The birds generally caught, in the order of their numerical importance, are, to mention a few: marsh snipe, *Gallinago megala;* Pacific golden plover, *Pluvialis dominica fulva;* bar-tailed godwit, *Limosa lapponica baueri;* and whimbrel, *Numenius phaeopus variegatus.* Godwit and whimbrel are generally hunted along open mudflats although they are occasionally encountered with marsh snipe and Pacific golden plover in paddy fields provided with soft soil and a little cover.

Ducks:—The ducks which, about two score years ago darkened the sky in the early evenings during their migration, are now a thing of the past, never to be witnessed by generations to come unless restoration measures are adopted by all countries visited. The ducks, although very much reduced in number, are still found in large bodies of water in many sections of the Philippines. While they were caught by the hundreds before the advent of effective firearms and speedboats, today a bag of ten using decoys and other modern contrivances is regarded as a sign of abundance of the bird and good luck for the hunters.

Nine species of migratory ducks have been recorded in the Philippines. Tufted duck, *Aythya fuligula;* garganey teal, *Anas querquedula;* and common pintail, *Anas acuta acuta* represent the majority of the migratory ducks killed.

Ducks begin arriving late in October and are available through April of the following year. The hunting season for this group of game birds, opens November 1 and closes the following January 31.

As for other game birds in the Philippines the hunting law on ducks is enforced to a certain extent only. Speedboats, camouflaged floating contrivances in the form of vegetation, airplanes, etc., are used in hunting wildfowl despite express provisions prohibiting them.

Migratory Non-Game Birds

A total of 83 forms of non-game birds consisting of herons and bitterns, hawks and their allies, gulls and terns, owl, nightjar, swifts, kingfishers and 36 forms of songbirds have been recorded as migrants in the Philippines. Among these migrants, however, the red-tailed shrike, *Lanius cristatus lucionensis* and Alaska willow warbler, *Phylloscopus borealis kennicotti* are most commonly encountered in towns and villages. In the vicinity of Manila, the red-tailed shrike and Alaska willow warbler fall heavily victim to snares, sling shots and air rifles during their residence in September, October and November every year. In an economic study of some birds of the Philippines it was incidentally found that the contrivances named above are operated largely by school children.

In a few places in the northern Philippines, the migration of grey-faced buzzard, *Butastur indicus* and pied harrier, *Circus melanoleucus* attracts considerable attention because of their immense flocks. In these places platforms several metres high are constructed. Each platform is provided with a roost for several birds and a blind for the operator. At nightfall, the operator carefully pulls down the wearied birds from the roost one by one.

RESIDENT PHILIPPINE WILDLIFE

The resident Philippine species of birds and mammals are offshoots of either Chinese and Japanese elements that apparently came through the northern Philippines, or Austro-Malaysian ancestors that probably came through the southern Philippines.

Their limited territory and the demand elsewhere for some of the native birds and mammals are contributory factors to their decimation. A rigid enforcement of our game laws and a concrete programme for the restoration of wildlife may, however, still save them from extinction.

Resident Game Birds

Luzon mallard:—Endemic in the Philippines. Recorded on many islands of the Archipelago. Small flocks of a few pairs may be seen feeding in small ponds. Its comparatively large size and its availability the year round to hunters and poachers result in a great scarcity of this bird.

Fulvous whistling duck:—Inhabits marshes where it is afforded natural protection from hunters, but not against reptiles and other predators. During the months of November, December, January, February and March the birds move out to lakes where they join the migratory ducks.

It is smaller than the Luzon mallard but its habit of forming flocks is detrimental as the bird is continuously hunted for its flesh. The opening of new roads further aggravated its existence as its natural habitat became more accessible to intruders.

Megapode:—Widely distributed over the Philippines but not common. Its habit of depositing a large number of eggs in the soil, in decaying debris or in the sand, and the instinct to group its nests together are disastrous to the species. The natives, familiar with the habits of the bird await its arrival on the breeding ground.

After the birds have deposited the big eggs, which the natives consider highly palatable, they are caught in snares. In several islands in the Sulu Sea the natives, in parties, have dared the high seas to reach the nesting grounds in time soon after laying. Thousands upon thousands of megapodes' eggs are destroyed every year by these sea-roving natives. The birds are snared and the eggs are collected for food.

Palawan peacock pheasant:—Found only in the island of Palawan. On the forest floor which it inhabits the bird is very wary. Its rarity and the beauty of the cock are apparently responsible for its demand in foreign zoos and museums. This is in addition to the fact that its flesh is used extensively for food by the natives. Moreover, the opening of lumber camps and new settlements for other purposes adversely affect the population of this fast disappearing species.

Red jungle fowl:—Found on many hills in nearly all the islands of the Archipelago. Frequents edges of second growth forest where the crowing of the male at intervals announces the presence of the birds. It is an ideal game bird, being wary, comparatively prolific, fairly neutral in its feeding habits and offers good meat for the table. It is for its flesh that it is much hunted by the natives, both Christian and non-Christian. Snaring, using a captive cock as a decoy, is the commonest way of catching the bird amongst the natives who have no shotguns.

Button quails:—Three species with several races are recorded in the Philippines. These are small birds of the open country. They take to the wing when flushed, but drop off after a short distance. The group as a whole is dimorphic, the females being larger and more beautiful than the males. Large numbers are caught by trappers using snares, nets and lights. The birds caught are used for export and for food. The spotted button quail, the largest of all the Philippine button quails, with a live weight of about 300 grams, is endemic to the island of Luzon, where it is rare.

Painted snipe:—A resident species, with females more brightly coloured than the males. The males are good examples of hen-pecked husbands, as they attend to the incubation of the eggs and rearing of the young. Unlike other snipe (it belongs to an entirely different family), this bird is weak on the wing, thus having less chance to elude hunters. Large numbers are killed along with migratory snipes during the open season for the latter.

Doves and Pigeons:—The habit of fruit pigeons of moving in flocks when feeding and drinking is disastrous as they are killed in large numbers in places they visit. Inasmuch as the time when the flock visits the feeding ground and the drinking pool is more or less determined, poachers need not waste much effort in obtaining them.

The green imperial pigeon and the spotted imperial pigeon represent the large pigeons, widely distributed in the Philippines. They inhabit very tall tree-tops in the forest, the fruits of which serve them as food. These pigeons are much hunted by the natives.

The medium-sized fruit pigeons of which there are no less than 20 forms, are typically represented by the pink-necked pigeon (*T. vernans*), a bird of the second growth. It is widely distributed in the Philippines. Big flocks are usually formed, especially when feeding on a tree. This habit, coupled with the fact that conservation measures are not enforced, accounts for its fast disappearance.

With the medium-sized pigeons may be included seven geographical races of bleeding heart dove which occur in different parts of the Philippines. This bird is one of the favourite pets amongst Philippine birds, and much in demand among fanciers, zoos and museums in foreign countries. The Luzon bleeding heart, endemic in Luzon and the adjacent Polillo Island, is frequently peddled in Manila as a caged bird. It is caught in snares. This and the clearing of the second growth for conversion into "Kaingin", or hill farming, practiced in many parts of the Philippines, are important causes of its decimation.

Still smaller are a number of doves widely distributed throughout the Philippines. One of them is the turtle dove, commonly seen on hillsides and edges of thickets. Near villages it may be seen by the roadside from which, when flushed, it proceeds to nearby rice fields or thickets. The birds move in pairs, although small flocks are often formed. The food consists of seeds of grain and of weeds, harm thus being inflicted to the crop when the rice is in head. The bird is much hunted for food. The barred ground dove is another of the smaller forms. It is more confident than other doves and this accounts for its being included in the bag of sling shooters and air riflers. Apparently as a result of constant danger, the bird has moved away from centres of population to the hillsides and thickets.

Resident Non-Game Birds

Some of the common resident game birds are indicated in the foregoing as undergoing decimation. A much larger number of resident non-game species also await government protection, otherwise many may perish. The opening of lumber and mining camps, conversion of hillsides into farms, and other means of destroying the natural environment without corresponding conservation measures, will always be detrimental to wildlife. Among the species of birds adversely affected by this changed environment are the following: hawks and eagles, parrots, cuckoos, swifts, trogons, bee eaters, hornbills, pittas or jewel thrushes, wood swallows, bulbuls, tailor-birds, flowerpeckers, sunbirds, flycatchers and orioles.

Monkey-eating eagle:—This rare endemic bird, *Pithecophaga jefferyi,* one of the biggest in the Accipitrine group, has been recorded in several islands of the Archipelago. It is, however, very rare where it occurs. Its rarity and magnificent commanding appearance probably cause its demand by foreign zoos and museums. The bird nests high up in very tall trees. It is usually caught by snares laid in frequented places, with puppies, baby monkeys or other small mammals as decoys. Although it is widely distributed, many records of its capture are from Mindanao. The white-breasted sea eagle, *Haliastur l. leucogaster,* common along sea coasts all over the Philippines, and a bird of wide distribution, is often confused with the monkey-eating eagle.

Mammals

The Philippines are comparatively poor in mammalian fauna. The land mammals are all resident and with the possible exception of the exotic Norwegian rat, they are on the decline. This is particularly observable among the big game, of which the following are worthy of mention.

Deer:—Found in almost all sizable islands except Palawan. In places accessible to motor vehicles, civilized man with his improved firearms is the greatest enemy of this animal. In the interior, non-Christians, some using the primitive bow and arrow and others modern firearms, depend on venison for their food. In many places trapping with the aid of retrievers is practised by both Christians and non-Christians. As in the case of other animals, buck, doe and fawn are indiscriminately taken. Clearing of forest areas by depriving the animal of its haunts is also responsible for the reduced population.

Mouse deer:—This (*Tragula nigricans*) is a small deer-like animal. Anatomically, it is different from the deer in many respects, thus belonging to a totally different family. Originally recorded only from the small island of Balabac, it has been observed recently in the vicinity of Southern Palawan. It is probable that it was introduced into the latter island by the natives who ferried it across Balabac Strait. Although it ranges south to the Malay Peninsula, the Philippine form has been observed to be very much depleted in its native haunts. Whether it will thrive well in its new territory in Palawan remains to be seen. Meanwhile, its tender venison is much sought for by the natives. Large numbers are caught with the use of traps and retrievers. Moreover, clearing of forest areas for settlement will enhance decimation of the species.

Tarsier:—The tarsier (*Tarsius* spp.) has been recorded in Samar, Leyte, Bohol and Mindanao. Its haunts are confined to certain definite localities within those islands. The growing need for this animal in the field of medical research, in addition to the demand for zoos and museums, presents a dark outlook for its future existence. Its habit of congregating and peculiarity of being attracted by light, so that it may be trapped in large numbers, will increase its decimation unless protection is extended.

Tamaraw:—The biggest and probably the least numerous of the endemic Philippine vanishing species is the tamaraw (*Bubalus mindorensis*). Smaller but more compactly built than the water buffalo (*Bubalus bubalis*), the tamaraw is confined to a limited area of about 400,000 hectares comprising three municipalities in western Mindoro. Those familiar with the haunts and habits of the animal doubt whether there are 1,000 living tamaraws now in existence.

Laws have been enacted and rules and regulations have been promulgated to effect its conservation, but they are good only on paper. Meanwhile, the demand for its flesh as food and for its horn and hide as trophies is very great. The natives have developed several ways of hunting this animal. They use domestic carabao bulls for decoys. When a bull tamaraw sees a bull carabao, he engages him in fight. When fighting ensues, the man who is hidden close by then fires at the tamaraw. Another method used by the natives is for the hunter to sit on a branch of a tree a few metres from the ground close to a place the animal frequents. There he waits for hours for an opportunity to fire if an animal appears. There are instances on record of airplanes being used in chasing tamaraw. Further, machine guns have been used in hunting this animal.

Wild hog:—This is not included in the list of protected or game animals owing to the fact that it is known to destroy crops. On the other hand, farmers are encouraged to kill the animal whenever it is found to be destructive to their property.

The animal is very prolific, a litter of six having often been recorded. The fact, however, that its pork is considered of superior quality to that of the domestic pig accounts to the animal being much hunted for food. This is the reason why the animal is now considered rare in places where it used to be abundant. Improved highways, modern motor vehicles and effective weapons are important factors in the decreasing number of Philippine wild hogs. Boar, sow and litter are indiscriminately killed.

CAUSES OF DECIMATION

A general view of wildlife conditions in the Philippines has been presented in the foregoing. It is shown that many species are on the decline. It is also shown that many migratory game species do not get protection, as it is alleged they are not protected in other countries they visit. In the desire to make this paper as brief as possible, discussion on many vanishing resident species of songbirds is not included. The causes of decimation are many and varied but may be grouped into:

1. *Effective firearms*: Imported automatic repeaters, repeaters, double barrels, submachine guns, etc., had been used in taking game in the Philippines for many years before the war. During the war, many firearms were confiscated by the Japanese. The records of the Philippine Constabulary show that over 500,000 shotguns of all calibres were licensed in 1941. In 1947 only about 10,000 shotguns were licensed. Untold numbers of firearms were not registered.

With the liberation forces came enormous numbers of firearms and ammunition of different types and makes. The people's desire to seek revenge, caused many with acquired firearms to turn to wildlife. Hunting became a favourite pastime of many people.

2. *Motor vehicles*: The motor vehicle is an important adjunct in the destruction of wildlife. With it, the hunters are able to chase game into the interior. On Sundays and holidays, groups of sportsmen leave towns and cities in motor vehicles for the woods in chase of game. During the war, nearly all available motor vehicles were commandeered. Only a few that escaped notice of the Japanese armed forces were spared. The liberation forces of the United States army brought a huge number of motor vehicles. The jeep proved very destructive for wildlife as it could travel on any kind of road and could penetrate deep into the forest. The records of the government show that in 1941 an aggregate of 56,000 motor vehicles were registered as compared to about 76,000 in 1947.

In addition to land motor vehicles, many U.S. surplus boats and planes were converted into peace time transportation. With these, isolated islands became accessible to travellers, including hunters in pursuit of wildlife.

3. *Network of highways*: With the inauguration of the commonwealth government some twelve years ago the Philippines embarked on a programme of extensive highways. This became most manifest in the island of Mindanao where a network of highways was necessary for development. The effect of this system of highways passable by motor vehicles to wildlife is obviously destructive.

4. *Opening of new settlements*: As a result of unevenly populated areas and the density of population in cities, the government opened new settlements in the course of its programme of developing the country. This necessarily altered the environment that for ages had been adapted to wildlife. Moreover, the people of the new settlements

have become a menace to wildlife in the neighbouring areas. Even before the government opened agricultural settlements, many other areas were cleared for mining and lumber camps, thus depriving wildlife of its natural environment.

The practice of "Kaingin", or hill farming, in many parts of the Philippines whereby the hillsides are cleared and cultivated is decidedly bad for conservation, particularly as regards soil, forestry and wildlife.

5. *Indifference to conservation of nature*: The fact that wild nature abounds in the Philippines, the cities being of very recent development perhaps accounts for the people's general indifference to conservation of natural resources. Indiscriminate cutting of trees, intentional burning of hillsides for conversion into farms, fish poisoning, and wildlife destruction are proofs of our lack of appreciation of Nature.

6. *Government supervision*: Confusion amongst government officials charged with the enforcement of conservation laws, results in their widespread violation. Jealousy, intrigue, political interference, aggravate the indifferent attitude of officials concerned with the execution of wildlife conservation.

SUMMARY

1. When the Imperial Japanese forces confiscated firearms and commandeered motor vehicles, conditions became favourable to Philippine wildlife.

2. Cessation of hostilities, resulting in enormous supplies of United States army surplus firearms, ammunition and motor vehicles, enhanced by the people's desire to kill, became a menace to wildlife.

3. There is an urgent need for understanding and co-operation among countries annually visited by migratory birds to save these creatures from decimation.

4. Wildlife conservation laws, rules and regulations are not enforced in the Philippines.

5. There is need for a programme to restore wildlife in the Philippines.

6. Large numbers of shore birds and ducks are indiscriminately killed during their annual migration as the result of poaching.

7. Among migratory insectivorous birds, the red-tailed shrike and the Alaska willow warbler are heavy victims of sling shots, air rifles and snares.

8. A number of important resident game and non-game birds and mammals are in process of vanishing as the result of indiscriminate killing and destruction of their natural environment.

9. Immediate causes of decimation of resident species of wildlife are effective firearms, numerous motor vehicles, network of modern highways, opening of new settlements like agricultural, mining and lumber camps, conversion of hillsides into farms, indifference to conserving natural resources, and lack of proper government control in wildlife conservation.

CONCLUSION

The advent of modern civilization and the lack of a conservation programme are important causes of decimation of many species of wildlife in the Philippines. Wildlife conservation in the Pacific area affecting myriads of migratory birds should be one of the concerns of the Pacific Science Congress.

THE PROTECTION OF RARE AND VANISHING FISHES

By George S. Myers, Stanford University

1. Introduction

Pressure for the conservation of living plants and animals has come almost entirely from three distinct sources, (1) persons interested in the continued abundance of food resources, (2) those who desire the preservation of the sporting recreations, hunting and fishing, and (3) scientists and nature-lovers who derive instruction and pleasure from the fauna and flora. The first group consists chiefly of the governmental conservation agencies, those private citizens whose general understanding of the problem of natural resources leads them to support protective legislation, and those in dependent industries who know that regulations are necessary to the continuation of their livelihood. The second group consists principally of sport fishermen and hunters, and is a really powerful force only in certain countries—especially English-speaking ones. The third group, the scientists and nature-lovers, is numerically weak everywhere.

In most countries, the first group concerns itself almost entirely with certain forest products (lumber, resins, etc.) and with the fisheries—which alone of the uncultivated animal food resources still produces richly. The second group is concerned chiefly with common species of mammals and birds which can be hunted and common fishes which may be caught with sport-fishing tackle. The third group is far more catholic in its interests, and may be said to exert some pressure for the conservation of all flora and fauna, but more especially for the protection of important rare or vanishing species.

However, this third group, the scientists and nature-lovers, has been uneven in the pressure it has exerted for the protection of the different groups of plants and animals. Whilst the botanists have been fairly consistent in their efforts to protect rare plant-species or floral assemblages of especial interest, the zoologists have confined their efforts almost wholly to the vertebrate animals, and to a very small part even of the vertebrates—the mammals and birds. Both botanists and zoologists have neglected the aquatic biota.

2. Neglect of Fish Protection

Due to the pressures exerted by the first two groups, regulations are in existence in most countries (whether or not they are well enforced) designed to assure a continuous high yield of food and game fishes. But in very few are there any regulations whatsoever for the protection of any other fishes, even though there are many species of great zoological or aesthetic interest which badly need such protection. Australia protects its living fossil, the lungfish, and the blind fish of Mammoth Cave, Kentucky, is also under protection, but I know of no other fishes of really great zoological moment which are protected solely on account of their zoological or aesthetic interest. Nor have the scientists and nature-lovers, who alone of the three groups concerned with conservation might be expected to take interest in this type of fish protection, ever displayed any especial interest in it. Parenthetically, it may be said that the problem is primarily, but not entirely, one concerning fresh-water fishes.

3. Conflict with Other Interests

Fresh-water fish resources in their natural state are endangered by many things—deforestation, fluviatile mining, introduction and management of game fishes for the benefit of sportsmen, and especially the utilization of water for several purposes, such as power and irrigation. It is impossible to justify any attempt to preserve fish faunas in their native state in most places because of the paramount importance of these water uses, nor do I propose any such justification. But I do deplore the general tendency of some fishery workers, especially those concerned with fresh-water game fishes, to consider every non-game species as of no importance whatsoever except as it may affect the production of game fishes. This tendency is in strong contrast to that of most terrestrial wildlife workers, who usually display a strong interest in the preservation of native birds and mammals.

4. Examples of Neglect

The United States has been especially assiduous in the protection of its wildlife. We point with pride to our great National Parks, which the dedicated, among other things, to the absolute protection of the flora and the fauna in its natural state. Hunting or tampering in any way with the flora or fauna in these parks is looked upon with horror by the National Park Service, and heavy fines are assessed against those who commit such sacrilege. Yet until very recently the Service permitted widespread heavy sport fishing in the streams of most of these parks, and actually assisted in the introduction of non-native and even exotic species into them. Apparently the official concern of the Service for the native fauna ended at the water's edge. Fortunately, a more enlightened policy is now being put into effect.

Again, we may take as an example the State of California, which has perhaps the best and most active fish and game department among the states. California originally had the finest series of native species of trout of any area of like size in the world. A really enlightened policy of game-fish management would have both exploited and protected these distinctive and geographically isolated trout species as an especial attraction to anglers, both within and without the state, at profit to the state's large tourist business. But several species of these peculiar trout, the San Gorgonio, Gilbert's and similar local forms, have been allowed to be overwhelmed and nearly or quite brought to extinction by neglect and continued restocking with the all-pervading rainbow trout. Nobody was interested—nobody took the trouble to interest the more intelligent sport fishermen—and the state fish and game department, without the incentive of aroused interest and pressure, found its energies occupied with other matters.

One more example will suffice. The isolated lowland patches, delimited by the coastwise spurs of the ancient uplands of south-eastern Brazil, support a distinctive fish fauna characterized especially by a strange series of *annual* Cyprinodont fishes—among the few truly annual fishes in the world and also among the most gaudily coloured of all living fishes. These tiny species (several of which I have had the opportunity of describing and naming myself) live in muddy ponds which dry up completely in the dry season. The species exist through the dry season only as tough-shelled eggs under the mud, and the new crop of fishes appears only when the rains have refilled the ponds. Extensive drainage projects in the lowlands, especially in the vicinity of Rio de Janiero, threaten the existence of several of these tiny but brilliant and zoologically important species. A small fish preserve of far less than a square kilometre, at Raiz da Serra, would preserve the most interesting of these species, but pressure of greater moment than one person can generate would be necessary to begin such a project.

5. REASONS FOR NEGLECT

The reasons for neglect of the protection of zoologically or aesthetically important fishes are several. Unlike birds, fishes are not easily observable by terrestrial human beings, and appreciation of the aesthetic appeal of fishes is confined chiefly to sport fishermen—who usually have no interest in non-game fishes. Ichthyologists are to blame for not bringing to light the information on threatened species and on zoologically important ones in need of protection. The present paper is the first one ever presented upon the subject, so far as I know.

When I first became interested in this problem a few years ago, I found that it would be impossible to begin any campaign for the protection of any non-game, non-food fishes in the United States, for two reasons: (1) there is no existing manual which enables all North American fishes to be easily recognized, and (2) there is no compilation or printed source-material for a compilation to tell us exactly what species are badly threatened. An appeal for funds for the compilation of a work on fishes, similar in scope to Allen's "Extinct and Vanishing Mammals of the Western Hemisphere", was considered by the American Committee on International Wildlife Protection, but finally came to nothing. Without such a compilation, a useful programme of fish protection even in North America cannot be gotten under way. But the efforts of one person are insufficient even to assure the necessary preliminary steps.

6. SUGGESTIONS

What is needed, in the first place, is at least a preliminary book or pamphlet on threatened species and those which, for one reason or another, it would be highly desirable to protect. Collection of the information for such a work, even if confined to one hemisphere, would be rather expensive, and publication would cost more. I know of no ichthyologist who would be in a position to do the job without funds.

My suggestion would be that this Congress (1) resolve that the protection of certain rare or vanishing fishes of great zoological or aesthetic interest is worthwhile and scientifically desirable, and (2) urge conservation agencies and organizations to consider conservation measures in regard to such species. I also suggest that the Congress include, as a member of its Committee on nature protection, one member—not a fisheries biologist—whose especial attention should be directed towards the conservation of important fishes in which the various fishery agencies are not interested.

DISCUSSION

Dr. Hubbs strongly supported Dr. Myers, saying that blind fish were now being protected in U.S.A., and that the official policy of the

U.S. Government that fresh-water species should be protected in national parks was now in force. The conservation policy does not end at the water's edge. Mr. Stokell also supported Dr. Myers, and referred to the fact that there was only a single fresh-water fish, the grayling, which was protected in New Zealand. He urged that protection should include the habitat. Mud-fishes were important in New Zealand and required protection. New Zealand waters had not been fully explored for native fish species and this should be encouraged because it was possible some were being exterminated by trout. The grayling had been wiped out from Westland by commercial exploitation and there had been no attempt to stop this. Mr. Hobbs said that legislation had now been enacted providing for the setting aside of suitable reserves for the preservation of fresh-water species. These were now being selected, but the legislation unfortunately did not give control of the river banks or surrounding country. Mr. Coolidge suggested that a resolution should be brought up later in the meeting.

Dr. Murphy mentioned that many non-commercial fishes were of importance as the food of birds, mammals, etc., frequenting fresh water.

THE IMPACT OF MAN UPON NATURE IN NEW ZEALAND

By Robert Cushman Murphy, American Museum of Natural History, New York

[*Abstract*]

In New Zealand, the most isolated habitable area of its size on earth, both physical and biotic evolution proceeded, until a few centuries ago, in the absence of a mammalian fauna, including man. Changes were induced after the arrival of Polynesians, but these were relatively slight until augmented by European influences in the latter 18th and early 19th centuries. Since then the aspect of landscape, and the composition of the flora and fauna, have been altered to an extent perhaps unequalled elsewhere in the temperate world. The author has recently returned from four months' travel in nearly every part of the Dominion. He has compared his observations with the findings and predictions of earlier scientific explorers and has prepared, as a basis for further investigation, a tentative description of the terrain and its natural resources in the light of probable future trends.

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Discussion

Mr. Kean said that New Zealand views agreed in general on control measures mentioned by Dr. Murphy except in the case of ungulates, control by poisons in New Zealand having been quite unsatisfactory. He referred to the difficulty of attracting deer with salt licks. Catnip had been tried for wild cats but was not proving satisfactory at present. The problem in New Zealand was to get poisons which would attract animals in thinly populated areas. The effort at present was directed towards improving the efficiency of the hunter.

Mr. Smith confirmed Mr. Kean's statements regarding the failure of salt licks for red deer in New Zealand. Licks had been left out for twenty years and had gradually been washed away.

Dr. Murie said that animals generally had to be trained to the use of salt licks where they had not been used to them. Food habits may have some influence on the desire for salt.

Dr. Cottam stated that the U.S. Wildlife Service had great experience in the use of poisons and he urged the greatest caution in using them. No one poison or lure can be applied universally. Poison is often only effective for a while and then has to be changed or supplemented; one lure or poison may be quite suitable in one area but quite useless fifty miles away. Poisons can, however, be a most effective and economical method of control if preliminary studies are fully and adequately made.

Mr. Kean described the method used in New Zealand to administer potassium cyanide, which had been found effective to control the opossum.

PROTECTION OF THE INDIGENOUS FLORA OF NEW ZEALAND

By W. R. B. Oliver, Wellington

A great deal has been accomplished in the past three or four decades in the way of providing reserves of various kinds for the protection of the indigenous plants of New Zealand. The Government has, indeed, with some prompting by such societies as the Royal Society of New Zealand, the Forest and Bird Protection Society, and sundry local societies and ad hoc committees, created National Parks, added considerably to the number of Scenic Reserves and passed an Act of Parliament giving general protection to the indigenous species in all public reserves, State forests, Crown lands, roads, and in private land without the consent of the owner. There is included in the Act a provision permitting the taking in reasonable quantities of any protected native plants required or intended for medicinal purposes or for purposes of bona fide scientific research, or nature study in schools or elsewhere, or for propagation in private or school gardens, provided that a protected species may not be taken in such a manner as to deplete the species in any one habitat.

The National Parks at present established in New Zealand are the following:

Tongariro National Park	150,000
Egmont National Park	79,000
Peel Forest National Park	1,305
Abel Tasman National Park	37,600
Arthur Pass National Park	146,400
additional area	150,000
Tasman National Park	97,800
Hooker Glacier National Park	38,000
Sounds National Park	2,407,000
Southern Alps (not yet named)	94,060
	3,201,165

The first five are administered by boards constituted by Acts of Parliament, with Commissioners of Crown Lands as chairmen, the remainder are administered by the Lands and Survey Department.

In addition to the National Parks there are many sanctuaries for the protection of the indigenous flora and fauna. These include the important islands Little Barrier, Kapiti and Resolution. Little Barrier and Resolution Islands are administered by the Tourist Department, Kapiti Island by the Lands and Survey Department. Scenic Reserves numbering 1,230 of a total acreage of 922,760, are administered by the Lands and Survey Department. Many large areas of forest and mountain tops are included in the reserves of the State Forest Service.

In selecting new areas for protection particular consideration should be given to the types of plant formations they contain. It should be the aim, in a general way, to protect, in several localities, each different kind of forest, scrub, grassland, mountain vegetation and swamp. At present probably the main types of forest are covered though not in a sufficient number of localities. One plant association, of especial interest to plant ecologists not only in New Zealand but throughout the world, is the kauri forest. The existing areas under kauri are small owing to the amount of timber cutting that has been done in the past. The best remaining kauri forest is situated within the drainage area of the Waipoua River, south of Hokianga Harbour. It is controlled by the State Forest Service, a Department that has the power of cutting timber in it, as, indeed, it already has done over a considerable portion. The kauri forest is a unique plant association and so Waipoua should be preserved intact so as to provide a study area for foresters, botanists, especially plant ecologists, and zoologists, as well as an attraction for tourists.

There are still many forested areas on the main islands, and there are some outlying islands, unsuitable for settlement which could be set aside as preserves for native plants. All the Subantarctic Islands might be constituted a National Park, or at least, if not already done so, declared sanctuaries for the preservation of their plants and animals, which constitute a very remarkable flora and fauna of Subantarctic type. The most outstanding example of an island that should be proclaimed a sanctuary, though more on account of its geological than its botanical features, is White Island in the Bay of Plenty.

An urgent necessity is a stock-taking of the plant associations of New Zealand with a view to determining what areas are required to be protected in order to ensure their permanent existence.

Discussion

Dr. Walker asked what part scientists took in an educational programme in New Zealand. Dr. Oliver replied that the Royal Society of New Zealand is especially interesting in this matter; and Dr. Falla mentioned the post-primary school bulletins produced by the Education Department, many being on science subjects.

EFFECTS OF THE AUSTRALIAN OPOSSUM (*TRICHOSURUS VULPECULA* KERR) ON INDIGENOUS VEGETATION IN NEW ZEALAND

By R. I. Kean and L. Pracy, Wildlife Branch, Internal Affairs
Department, Wellington

Introduction

The Australian opossum, *Trichosurus vulpecula* Kerr, of the Family Phalangeridae, was first introduced into New Zealand about the middle of the last century.

It is a highly variable animal, classified into some eight sub-species which interbreed.

Records of early introductions are not complete, and unrecorded (and unauthorized) liberations have been made repeatedly, so the present New Zealand stock is a mixed one which cannot as yet be adequately classified, varying from place to place.

The opossum proved to be easily acclimatized, and numbers increased rapidly. It soon showed itself capable of doing considerable damage to orchards, exotic tree plantations, and gardens, but its effect upon indigenous forest has for many years continued to be the subject of sharp controversy, at least in part due to imperfect observation, for damage occurs predominantly in the higher forest strata and so is not readily observable from ground level. Further, effects are masked by the animal's strong preferences for definite species which may result in the local extermination of favoured plants in a forest that remains normal at first sight although the hidden changes may have far-reaching consequences.

RANGE

The opossum is largely an arboreal animal, and, although it may be found on grassland, its occurrence there is considered to be colonization of an unnatural habitat which is permitted by an otherwise especially favourable environment.

Certainly, opossums do not establish themselves on grassland under rigorous climatic conditions. At the higher altitudes, they may be found from time to time, travelling across the tussock grasslands above the upper timber or scrub line which occurs at 900 metres or slightly higher. Faecal pellets may be found extending for some hundreds of yards into the tussock, testifying to summer feeding there, but, although severe damage may be suffered by the scrub belt plant species, the near presence of trees appears to be necessary for the permanent holding of a population of any density.

A seasonal vertical movement takes place. This consists of a summer downwards trend towards the damper valley systems and a winter movement to the higher slopes which frequently are warmer at that season, and have a lower air humidity.

Accordingly, forest damage must be expected at all levels below the upper shrub line, but the plants of the tussock grassland formation are little affected. Damage is often of greatest significance at the higher altitudes, for the reduction in the numbers of species due to increasing coldness of climate, tends to group palatable species together in almost pure associations, which may be wiped out en masse, instead of as individual plants interspersed among mixed associations as found at lower levels.

FOOD

The feeding pattern of the opossum is distinctive, and it is determined mainly by the size of the animal, the position it assumes when feeding, and its practice of holding food in its forepaws while eating. It is characterized by the outline of leaf fragments left, typically an entire petiole bearing a small basal portion of blade with protruding midrib, and by the relative defoliation of different parts of a tree.

Significant deviation from the type patterns may occur in a variety of ways. In the case of a few species, young leaves only are eaten, which tends to produce trees which bear reduced foliage, but in the absence of the usual signs, the reason for the reduction is not apparent.

Leaves: These provide the bulk of the food of the opossum, and the most serious form of tree loss results from death caused by persistent defoliation.

Commonly, mature leaves are eaten, but in some cases buds, young leaves, or petioles are taken exclusively. Over 70 indigenous tree species have been listed as foods and to this must be added some 20 species of ferns, and a few vines and epiphytes. Grasses and sedges are eaten but were rarely found in stomach contents. These plants do not lend themselves to field observation, in that effects of opossums on them cannot be distinguished from those of other animals, but it appears that they are not normally eaten to any extent and opossums which utilize grasslands are mainly dependent upon forbs.

Many of the tree species do not suffer heavily, and although they are eaten, it is not certain that they could support life unless supplemented by more palatable species.

Strong preferences are shown for definite species, but marked differences in order of palatability are found in different districts. This, as with choice between young shoots and leaves, cannot be adequately explained. It does not appear to be explainable by racial differences in the opossums. Probably the answer lies mainly in the balancing of different food combinations—the building up of adequate proteins, and the blending of semi-poisonous alkaloids. In some cases, differences in palatability are obviously due to local growth forms, the epharmonic variations of plants.

Bark: Owing to the ease of its observation, bark biting has frequently been accorded greater significance than is due. Some 70 tree species have been recorded as subject to this form of injury, and any tree may be affected lightly.

The baring of wood appears to facilitate the entry of boring insects and fungi, but loss through these causes cannot be evaluated.

Death of tree of 16 species occurs fairly frequently, sometimes caused by direct injury, but more frequently by overshading by other trees of species which are not attacked.

Bark is utilized as food mainly in wet or windy weather, and accordingly, its incidence does not provide a reliable index of population density.

Evaluation of the significance of bark injury in respect of bird life, protection forests, and timber production is not attempted, but in the last respect it can be noted that of timber trees kaikawaka (*Libocedrus bidwillii* Hook) and saplings of totara (*Podocarpus* spp.) and red beech (*Nothofagus fusca* Oerst.) are all attacked fairly severely.

Flowers: Sixteen species have been listed from field observations, but few were found in stomach contents. Probably low availability, or shortness of flowering seasons accounts for the low level of utilization, although large quantities of northern rata flowers were found to be taken.

Fruits: Thirty-eight succulent fruits have been found to be eaten, and, according to stomach analysis (Mason) they "are of importance from midsummer until late autumn when they were almost of as much importance as leaves". This, of course, corresponds with the period of availability. The actual consumption or destruction of fruit is greater than stomach contents indicate. Fruits such as tawa, hinau, miro, etc., are taken while green and incompletely developed, and frequently only part of a fruit is eaten. In the case of tawa, the half-grown fruits are taken in large numbers for the soft seed kernels, which are extracted from holes made in one end of the fruits. Many of these would be required to provide even a small volume of stomach material.

Wastage is considerable. In addition to the loss caused by partly-eaten fruits, undamaged berries are knocked from the trees in large numbers. During a single night, the ground beneath pigeonwood, karaka or hinau trees may become littered with undamaged fruits, broken from the trees singly or in clusters. In general, it is the larger fruits which suffer in this way.

Food Preferences: Leaves constitute the staple food of the opossum. They are replaced to some extent by flowers of a lesser number of kinds, and by succulent fruits, as these become available, mainly in late spring to early summer, and in midsummer to late autumn respectively. Bark is a bad weather standby food. Apart from the influences of other types of food, leaves have a special attraction during the spring early growth period, and conversely lose palatability during the slow or arrested growth period of late autumn and winter.

A further seasonal change is shown in the usage of the fivefinger tree (*Nothopanax arboreum* Seem. and *N. colensoi* Seem.), in which the bases of the leaf petioles are eaten as a winter food. This appears to be a result of seasonal restriction of choice of food.

Relative palatability has been assessed according to average utilization, irrespective of proportional representation of the respective plant species in the vegetation. Availability, for the opossum, has been regarded as equal for all trees and shrubs which occur in significant numbers, because even one tree of a preferred species may have sufficient attraction to cause the establishment of a home territory. Indeed, restricted availability may sometimes result in exceptionally heavy relative utilization.

There is general agreement between field observations and stomach analysis (Mason). Such differences as occur are largely explainable by the sampling methods of stomach taking, which were not designed primarily for the assessment of palatabilities. It might be questioned whether the frequencies method used for the limited number of stomachs available would give the same result as a quantitative analysis, but Miss Mason points out that differences would be slight on account of the very small average number of foods found per stomach, the mean being 3·1 species (Range: 1-9. Standard deviation: 2·3.)

Konini is a common first favourite, but in Poverty Bay, Stewart Island and Mount Egmont, it ranks fourth, fifth and seventh respectively. Wineberry, another tree of frequent first choice falls as low as eighth in the Ruahine Ranges. These trees illustrate the rule, which holds also for species of lower palatability.

The main significant plant species have been grouped into four classes, Table 1, according to degrees of use, but local variation may result in a general Class I species falling into Class III, and vice versa.

TABLE 1

LEAVES CLASS I: HIGHLY PREFERRED FOOD PLANTS.

(a) *Early seral or arrested climax trees*

konini, BN	*Fuchsia excorticata* Linn.
wineberry, B	*Aristotelia serrata* (syn. *A. racemosa* Hook. f.)
fivefinger, B	*Nothopanax orboreum* Seem.
raukawa, B.	*Nothopanax edgerleyii* Harms.
rangiora	*Brachyglottis repanda* Forst.
tutu, B	*Coriaria ruscifolia* Linn.
leatherwood	*Senecio elaeagnifolius* Hook. f.
kamahi	*Weinmannia racemosa* Linn.

(b) *Forest edge trees*

titoki, B	*Alectryon excelsum* Gaertn.
kohekohe, B	*Dysoxylum spectabile* Hook. f.
houhere	*Hoheria* spp.
pohutukawa, N	*Metrosideros tomentosa* A. Rich.

(c) *Late seral or climax trees*

rata, northern, N***	*Metrosideros robusta* A. Cunn.
rata, southern, N***	*Metrosideros umbellata* Cav.
toro, b**	*Suttonia salicina* Hook. f.
mangeao, T***	*Litsaea calicaris* Benth. & Hook. f.

(d) *Herbs*

punui	*Stilbocarpa lyalli* Armstr.

LEAVES CLASS II: PREFERRED FOOD PLANTS.

(a) *Early seral or arrested climax trees*

kanuka**	*Leptospermum ericoides* A. Rich.
mahoe B**	*Melicytus ramiflorus* Forst.
ngaio B**	*Myoporum laetum* Forst.
— *	*Gaultheria rupestris* R. Br.
mutton bird scrub*	*Senecio rotundifolius* Hook f.
**	*Nothopanax colensoi* Seem.
**	*Nothopanax simplex* Seem.
*	*Nothopanax sinclairii* Seem.

(b) *Forest edge trees*

lowland ribbonwood	*Plagianthus betulinus* A. Cunn.
maire-tawake B	*Eugenia maire* A. Cunn.
pate B	*Schefflera digitata* Forst.
—	*Pittosporum ralphii* T. Kirk.
—	*Olearia arborescens* Cockayne & R. M. Laing.

(c) *Late seral or climax trees*

maire B*** B	*Olea* spp.
totara TB*** P	*Podocarpus totara* D. Don & *P. hallii* T. Kirk.
hinau B***	*Elaeocarpus dentatus* Vahl.
pokaka B**	*Elaeocarpus hookerianus* Raoul.
tawa TB***	*Beilschmiedia tawa* Benth. & Hook. f.
akepiro*	*Olearia furfuracea* Hook. f.

(d) *Lianes*

pohuehue B	*Muehlenbeckia* spp.
rata vine	*Metrosideros scandens* Soland.
rata vine	*Metrosideros diffusa* A. Cunn.

(e) *Epiphytes*

	Astelia solandri A. Cunn.

(f) *Ferns*

Wheki	*Dicksonia squarrosa* Swartz.
Prickly shield fern	*Polystichum vestitum* Presl.

LEAVES CLASS III: GENERAL FOOD PLANTS.

(a) *Early seral or arrested climax trees*

karamu B	*Coprosma lucida* Forst.
raurekau B	*Coprosma australis* (syn. *C. grandifolia* Hook. f.)
koromiko	*Hebe* spp.
leatherwood	*Olearia colensoi* Hook. f.

(b) *Late seral or climax trees*

mapou **	*Suttonia australis* A. Rich.
pigeonwood B**	*Hedycarya arborea* Forst.
lancewood **	*Pseudopanax crassifolium* C. Koch.
kaikomako B**	*Pennantia corymbosa* Forst.
red beech T***	*Nothofagus fusca* Oerst.
brown beech t***	*Nothofagus truncata* Col.

(c) *Lianes*

supplejack	*Rhipogonum scandens* Forst.
clematis	*Clematis indivisa* Willd.
rata vine	*Metrosideros perforata* A. Rich.

(d) *Herbs*

Few grasses, sedges and forbs

(e) *Ferns*

	Blechnum fluviatile Salom.
	Blechnum lanceolatum Sturm.
	Asplenium bulbiferum Forst.
	Pteridium aquilinum Hook. f.

LEAVES CLASS IV: UNPALATABLE PLANTS.

(a) *Early seral or arrested climax trees*

manuka	*Leptospermum scoparium* Forst.
tauhinu	*Cassinia leptophylla* R. Br.
—	*Coprosma* spp. (small leaved)
turpentine wood	*Dracophyllum* spp.

(b) *Forest edge trees*

karaka	*Corynocarpus laevigatus* Forst.
heketara	*Olearia rani* (syn. *O. cunninghamii* Hook. f.)
akeraho	*Olearia paniculata* Cheesem.
—	*Myrtus* spp.
putaputaweta	*Carpodetus serratus* Forst.
lemonwood	*Pittosporum eugenioides* A. Cunn.

(c) *Late seral or climax trees*

rimu TB***	*Dacrydium cupressinum* Soland.
miro TB***	*Podocarpus spicatus* R. Br.
matai TB***	*Podocarpus ferrugineus* D. Don.
silver beech T***	*Nothofagus menziesii* Oerst.
rewarewa ***	*Knightia excelsa* R. Br.

PALATABLE FRUITS

totara	*Podocarpus totara* D. Don., *P. hallii* T. Kirk.
kahikatea	*Podocarpus dacrydioides* A. Rich.
matai	*Podocarpus spicatus* B. Br.
miro	*Podocarpus ferrugineus* D. Don.
rimu	*Dacrydium cuppressinum* Soland.

hinau	*Elaeocarpus dentatus* Vahl.
pokaka	*Elaeocarpus hookerianus* Raoul.
taraire	*Beilschmiedia taraire* Raoul.
tawa	*Beilschmiedia tawa* Benth. & Hook. f.
karaka	*Corynocarpus laevigatus* Forst.
kohekohe	*Dysoxylum spectabile* Hook. f.
titoki	*Alectryon excelsum* Gaertn.
wineberry	*Aristotelia serrata* (syn. *A. racemosa* Hook. f.)
maire	*Olea* spp.
maire tawake	*Eugenia maire* A. Cunn.
horopito	*Pseudowintera axillaris* (*Wintera axillaris* Forst.)
kawakawa	*Macropiper excelsum* Miq.
nikau	*Rhopalostylus sapida* Wendl. & Drude.
kohia	*Passiflora tetrandra* Banks & Soland.
lawyer	*Rubus australis* Forst.
poroporo	*Solanum aviculare* Forst.

B = succulent fruit — bird food.
N = nectar — bird food.
T = timber.
*** = main canopy tree — climax.
** = shade tolerant sub-dominant tree.
* = scrub.
Letters in small type indicate lesser importance.

HOME RANGE

The term "home range" is here employed to describe the area of habitual usage of an individual or a family group, which is undefended against intrusion by other animals.

It appears to consist of a system of runways along the ground and on trees, rather than a solid block. No evidence has been found which has indicated that true defence ever occurs. Defoliation of groups of trees may occur so quickly that it can be attributed only to combined work of a number of opossums, and as many as six have been found sleeping together in the one hollow tree. Such fighting and eviction from nest sites as occurs can be regarded as sexual antagonism or defence of the nest during the breeding season, when a member of either sex may fight.

The significance of home range lies in its effect upon browsing pressure and upon rate of spread.

Frequently, one tree may be found to have been depauperated by heavy browsing which has been continued for a long time, while neighbouring trees of the same kind have remained relatively unaffected. Death of such a tree, either by simple defoliation or by overshading by unrestricted adjacent trees, would not happen if browsing pressure were spread, and these losses which are caused by utilization which has been continued after availability of food has fallen far below that of other trees in the same area, are attributed to habit or to a relatively stable home range.

Heavy concentrations of population are tolerated and, in badly infested country in Poverty Bay, concentrations in isolated patches of forest or scrub opossums have been taken both by government wildlife personnel and independent persons at the rate of 20 or more per acre. Accordingly, dispersion of opossums is likely to be affected more by the availability of food and cover than by pressure of actual numbers, although individual animals, presumably travelling, are sometimes found in unsuitable country. In the absence of any discernible reason for movement, it seems probable that a migratory tendency may be developed at some stage of life.

It has already been stated that opossums do not thrive in damp cold conditions. These are frequently found in indigenous forest which has remained unmodified by browsing animals, and they appear to have a significant effect upon rate of spread of opossums which is attributed to restricted mobility and to lower productivity, due both to reduced fertility and to higher death rates of post-pouch young and adults. Evidence to establish these views is by no means complete, but they are supported by the animal's general avoidance of dampness and heavy undergrowth, by its apparent slowness of spread in undamaged forest followed by rapid increase in the wake of deer or other animals which open up and dry bush country, by the increased numbers found in the vicinity of former tracks, and by the apparent greatly increased birth rate in a dry climate.

Opossums may thrive in heavy wet bush as on Mount Egmont in Taranaki and in Westland, but this does not invalidate the former statement. Opossums' fur wets readily and the bedraggled animals found in traps after rain soon die. In continuous rain, traps do not catch during the first few nights, while captive opossums largely remain inside their boxes. But a wet habitat may become modified by the continued use of a number of animals. The establishment of tracks and shelters and the effects of browsing enable opossums to traverse their home ranges without undue contact with wet vegetation, and the profusion of growth associated with heavy rainfall reduces the distances which have to be covered in feeding; so that settled colonies do well, and may even spread fairly rapidly provided sufficient density of population is maintained to control growth of vegetation, when spread results from the continuous pushing onwards of the boundaries of occupied areas, instead of the setting up of scattered homes by pioneers in new country.

The effects of the opossum in the absence of other browsing animals is seldom seen, but Codfish Island, off the north-west coast of Stewart Island, is of interest in this respect. The main bush there is trackless, but it is not too heavy to prevent movement. Opossums are found distributed sporadically throughout in small numbers except in the coastal belt where penguins (*Megadyptes antipodes*) and mutton birds (*Puffinus griseus*) have assumed the role of the usual ruminants in reducing undergrowth and forming tracks. There, opossums are most numerous, and on the northern coast a widening band of denuded trees, shrubs, and ferns, encroaches upon the still unaltered forest.

BIRDS

Occasional traces of fledglings or of eggs have been recorded in stomach contents (Kirk, Perham) but it does not appear that these are sought after, or form a natural food. No definite evidence has been encountered by the present writers. It could be expected that an animal endowed with the teeth and curiosity sufficient to induce it to open sealed tins of condensed milk would not be averse to sampling any other unusual object encountered.

Birds appear to become more plentiful when opossum numbers are reduced, and decline again with the influx of fresh animals from untrapped areas, but no precise census has been attempted.

The most serious effect upon birdlife, however, would be the competition for food, either directly through the use or wastage of fruit and flowers, or indirectly by the destruction or depauperization of trees by defoliation. It has been suggested (Kirk) that the general large quantities of untouched fallen fruits indicates super-abundance of supply, but the inference is misleading. The question to be asked is whether the immense destruction of flowers and fruits at all stages of growth limits bird numbers by shortening the period during which fruits are available, by the elimination of early and late fruits. Then there is also the case of the abnormal season, when unseasonable storms result in the loss of crops, such as occurred in the Orongorongo Valley in 1947 when a southerly storm, during the period 14th to 17th February, destroyed most of the konini berries which had previously been used for feeding the captive opossums. Further, there is to be considered the case of the local extermination of species such as konini (*Fuchsia excorticata* Hook.) and rata (*Metrosideros robusta* A. Cunn., *M. umbellata* Cav.) by defoliation.

It is shown also (Falla) that insectivorous birds must be deprived of some of their main food supply by defoliation, and that the removal of certain rain-turning leaves reduces the safe nesting sites available for the nesting of the fantail (*Rhipidura flabellifera*), which cannot nest in thickets.

Discussion

In the tabulation of food plants, prominence has been given to those species which suffer from defoliation—those species that provide leaves as food, and, accordingly, are most frequently killed by the opossum. These have been roughly classified as to function. Early seral plants are ones which colonize denuded ground such as slip faces, burns, and old flood plains, etc. Forest edge trees are of a type which provide ultimately for the lateral extension of climax forest and also function as wind breaks. The subdivisions (and even the classes) cannot be regarded as clear cut, and they suffer from over-simplification. The lists are not complete, and Classes III and IV, plants of low priority and unpalatable plants respectively, could be lengthened considerably.

The precise long term effect of the opossum cannot yet be defined, because few areas have yet held heavy populations for a long enough period, but we believe that all plants in Class I are likely to suffer local extermination, while those of Class II are liable to serious reduction at least.

It is noticeable that only one indigenous timber tree, mangeao, is found in the high preference Class I, and only two timber trees, totara and tawa, in Class II.

On the other hand, the early colonist species which re-cover bare ground, and which form the preclimax associations which have the permanent function of protecting steep ground against slipping and sheet erosion, are most prominent in preference Classes I and II, not only in respect of number of species, but also in respect of actual ground coverage.

Forest edge species which also function in normal forest recovery or regeneration, are similarly prominent in Classes I and II.

In respect of birds, which are believed to be of considerable importance in forest maintenance, the situation is summarized (Falla) by the statement that the reported situation discloses a serious dislocation of bird economy and must impose critical restrictions on their normal food and cover requirements.

There are no known satisfactory natural checks to counter the increase of opossums. Early writers (Cockayne, 1928; Kirk, 1920; Uren and Perham, 1928) consider that the value of the fur would provide ample incentive to trapping which would keep populations low. This view has been shown to be incorrect.

In the better class of trapping country, trappers have tended to maintain opossum populations at higher levels than their blocks can support indefinitely, and the steepest parts of blocks, where the country is most vulnerable to soil erosion, are left untouched owing to difficulties of trapping. These areas, as intended, retain seed stock for replenishment of the depleted easy country. Unfortunately, however, their vegetation is composed of those early seres which provide the most palatable opossum foods. These areas, accordingly, carry heavy populations without respite, so, although the greater part of a block may remain in fair condition, forest destruction and soil erosion is frequently in, or approaching, a serious condition.

A worse situation is found in respect of country which is not suitable for commercial trapping by reason of poor quality fur, difficulty of access, or unsatisfactory trapping conditions (as in scrub land). This type of land, in the aggregate, amounts to a considerable area.

23,000,000 acres, over one-third of the total land area of New Zealand, is under forest or scrub (*D.S.I.R. Bul. 77*). Opossums are not found throughout the entire area (their exact limits are not yet known) but their ultimate spread to all parts is probable under present conditions, and adequate inspection and control methods are needed urgently.

The above figures indicate the area which comes within the scope of this present paper, but the opossum is found over a wider area and is a pest in settled land, gardens, farms, orchards and plantations where suitable cover is available. Investigation of the many problems caused by this animal is proceeding.

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SOUTHERN SEALS: POPULATION STUDIES AND CONSERVATION PROBLEMS

By R. A. **Falla**, Dominion Museum, Wellington

[*Abstract*]

Fur seal stocks of the southern coasts of New Zealand and adjacent Subantarctic islands, are historically noted for their former abundance and the rapid rise and fall of an unregulated industry in the early years of the 19th century. A negligible remnant has since been known to survive, and a policy of close seasons has been maintained by the New Zealand Government for more than half a century, with one or two experimental open seasons and a certain amount of poaching.

Following reports of substantial increase, and a short open season in certain areas in 1946, an investigation has been undertaken for preliminary survey. The shore terrain inhabited by fur seals is difficult of access, and census counts are hard to make. The total population, however, is estimated to be relatively small, considerably less than 50,000 animals, scattered along two or three hundred miles of coastline, and islands 100 miles or so apart. There appears to have been some increase in numbers in the northern part of the range and less in the south. The breeding season is December, and the rookeries are occupied for nearly nine months. There is no season at which all seals are absent, and no evidence of strong or regular migratory movement.

Information on feeding habits, as far as available, is discussed, and the problem of isolating age groups and estimating their numbers under conditions obtaining in New Zealand and probably elsewhere in the South Pacific is compared with the known habits of Alaskan fur seals and the consequent organization of the fur industry in that region.

REGENERATION OF THE VEGETATION OF GREAT KING ISLAND

By G. T. S. **Baylis**, University of Otago, Dunedin

The Three Kings Islands lie about 30 miles from the north-west extremity of the North Island of New Zealand. They have never been occupied by white settlers, and are too remote and inhospitable to attract fishermen or yachtsmen—in short, they are well insulated from casual interference, and make an excellent natural sanctuary. They were gazetted as such in 1930. Unfortunately, the isolation of the Group had been appreciated some centuries prior to this by Maoris unable to hold their own in tribal wars on the mainland. They had settled on Great King Island, and appear to have cleared practically all the forest. They departed about 1840, when British administration checked tribal feuds, but after this a large goat population developed and interfered with regeneration. By 1945 the island had a sadly depleted appearance—a very monotonous cover of *Leptospermum* shrubland or light forest. The only fair-sized area not in *Leptospermum* carried a sward of coastal grass.

The destruction of the original vegetation of Great King Island is especially regrettable because it must have been peculiar in many respects. It had several unique components—seven trees, a shrub, a large woody liane and a fern are endemic in the Group. In addition, certain non-endemic species played an unusual part in the structure of the vegetation, particularly the handsome Araliad *Meryta sinclairii.* It is unlikely that the smaller islets of the Group, which are almost inaccessible and have been very little explored, preserve all of what has been lost from Great Island, which exceeds its largest satelllite in height by 300 feet and in area about a dozen times. It contains the only sheltered valley with a permanent stream in the group. Two of the endemic species are known only from a single specimen growing among the *Leptospermum* on the higher part of Great Island, and it would not be surprising should they prove not to occur on the islets. Where two species are reduced to a single specimen, no doubt there have been others now wholly extinct.

So far this has been a lament for a vanished vegetation—an over-familiar theme. What follows is more encouraging. In 1945 Mr. Powell, the Acting Director of Auckland Museum, successfully urged the removal of the goats from Great King Island. In April, 1946, a party from the Wildlife Branch of the Internal Affairs Department went to the island and destroyed every goat—a commendable effort, since there were nearly 400 of them, and many scrub-covered cliff ledges and screes to provide cover. This intervention seemed to have come rather late, and little change in the vegetation was expected until several years had elapsed. But in December, 1947, 19 months after the goats were shot, it was obvious that despite centuries of interference, appropriate seral communities of indigenous plants had begun to appear as soon as the alien goat factor was removed—coastal herbs on bare ground, *Leptospermum* seedlings on the grass swards, dense though these were, and seedlings of climax forest dominants beneath mature *Leptospermum* forest. Specially remarkable was the fact that *Meryta* seedlings were often numerous enough to ensure that the *Leptospermum* canopy would be replaced by a *Meryta* canopy although there were no parent trees on the island, nor had this species grown there for at least 60 years. The drupes are eaten by gulls, and these had apparently brought quantities of seed from the other islands, one to three miles distant. Mr. Powell spent a few hours on Great King Island in November, 1948, and he informs me that there are already extensive thickets of young *Brachyglottis arborescens.* This is one of the local endemics which in 1945 was reduced to two small groups of dying trees.

It appears that, despite the centuries over which alien factors have operated, the original plant cover will return, and the time required promises to be surprisingly brief. We shall be provided with an example which should encourage similar conservation measures elsewhere, and which suggests that artificial propagation of rare species in a depleted area should not be attempted until an opportunity has been given for natural re-establishment.

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DISCUSSION

Dr. Hubbs considered that this paper on the control of goats and resulting recovery of vegetation was of special significance in that it offered hope for other goat-infested islands on which little vegetation remained. In reply to a question from Professor Gordon as to the distance to the islands mentioned which acted as seed reservoirs, Dr. Baylis replied that the distance was 1-3 miles; and to a question as to whether it was possible that seed had remained dormant on the island and would be responsible for the regeneration, said that there was no evidence on this point.

THE RELATION OF THE UNIVERSITIES TO RESEARCHES IN THE CONSERVATION OF THE FISH AND WILDLIFE RESOURCES OF CANADA

By W. A. Clemens, Department of Zoology, University of British Columbia, Vancouver, B.C., Canada

[*Abstract*]

The great majority of the Universities of Canada have been interested from the times of their foundations in the problems related to the conservation of the fish and wildlife resources of the Dominion. The earliest interest was stimulated by the institution of the Biological Board of Canada for the investigation of fishery problems. Subsequently, the organization of Provincial divisions gave added impetus. In more recent years Dominion and Provincial programmes in wildlife research have opened up additional fields.

The Universities have contributed significantly to the advancement of the conservation programmes throughout the Dominion by the training of students, by the participation of staff and students in the investigation programmes and by undertaking fundamental researches.

CONSERVATION OF THE TRUMPETER SWAN IN CANADA

By J. A. Munro, Dominion Wildlife Service, Canada

Introduction

The trumpeter swan, *Cygnus buccinator* Richardson, at one time included in the category of vanishing species, is believed now to have attained a numerical status which places it beyond danger of extermination in the forseeable future. This result has been achieved, during the past 28 years, by an organized programme of conservation. The programme has entailed, among other things, the discovery of wintering and nesting areas, protection by paid wardens of the swans that inhabit these areas, winter feeding of barley in certain areas where the need is indicated, and continued appeals to the Canadian people for co-operation in the work of saving this unique waterfowl. The purpose of this paper is to review the history of a successful enterprise and to summarize present knowledge of the status, distribution, and life-history of the species.

Conservation Measures

The protection of the trumpeter swan was initiated in 1916 when the Migratory Birds Treaty between Great Britain and the United States was signed. The Canadian Parliament fulfilled its obligation under the Treaty by passing, on August 29, 1917, the Migratory Birds Convention Act, under authority of which suitable protective regulations were adopted. The Migratory Bird Treaty Act was passed by the United States Congress in 1918. Under these respective enactments it became unlawful to hunt, molest, kill, or have possession of any native species of swan, the killing of which had hitherto been permitted under the existing laws in many States and Provinces.

However, no special endeavour was made immediately to study the problem of trumpeter swan conservation. Practically no information concerning the distribution of the species was available. Well-informed ornithologists thought that the trumpeter swan population did not exceed 25 individuals and that current reports of swans observed in British Columbia could be referred to the common species, *Cygnus columbianus* (Ord).

The discovery in 1919, at Vaseaux Lake in the Okanagan Valley, British Columbia, of a wintering population of 20 or more trumpeter swans, nearly equal in number to the supposed total population, led the administrators of the Migratory Birds Convention Act to believe in the probable existence of other such bands. It was decided that a search for these should be made and appropriate methods of conserving them undertaken should any be found.

In the meantime Vaseaux Lake was established as a Federal Bird Sanctuary under the Migratory Birds Convention Act, and a warden service was put into operation there. This resulted in satisfactory protection for these swans against human enemies. Although an annual fluctuation in numbers took place, the number of cygnets among the population indicated that a reasonably successful future for them might be anticipated. Unfortunately, in January, 1925, the band of eight adults and eight cygnets then inhabiting the lake was decimated by lead poisoning, as will be explained later in this account.

During these early years, efforts to locate other wintering bands met with increasing success and wardens were employed to guard those which, less remote than others, were endangered by possible human interference. Later it became necessary, as more facts were obtained, to provide for the winter feeding of bands thought to be endangered by starvation. At the same time public co-operation in this endeavour was solicited by means of the press, the radio, public addresses, and the distribution of questionnaires seeking information as to the location of trumpeter swans both in summer and in winter. The personnel of the Royal Canadian Mounted Police and provincial game authorities also took part in this publicity programme, and in the enforcement of legal protection.

A mass of detailed information which necessitated continual expansion of warden service and other related activities was thus obtained. At present assistant migratory bird wardens are employed at Tweedsmuir Park, at Lonesome Lake on the Atnarko River, at Tachie River, at Graham Island, Queen Charlotte Islands, and at the Itatsoo Lake and Vaseaux Lake Bird Sanctuaries. The winter population of trumpeter swans in these several areas is approximately 470.

In addition to these populations under special protection are numerous others, some in still more remote parts of British Columbia where it has not been possible, and is perhaps not yet necessary, to institute warden services. Furthermore there are numerous small bands, up to 10 or so, which winter more or less regularly on rapid stretches of inland rivers, on the usually ice-free ponds and larger lakes on Vancouver Island, and at the heads of inlets on the mainland coast. It is not an exaggeration to say that trumpeter swans, at one time or another during the winter, visit most of the many lakes on Vancouver Island and along the mainland coast. The number fluctuates from year to year but probably exceeds 600 individuals. Thus the winter population is believed to approximate 1,000.

In summary it can be stated that wintering populations of trumpeter swans are distributed over the western half of the province of British Columbia between north latitudes 49° and 55°. There are populations at numerous places on the long coastline. Some of these frequent lakes and rivers at points distant from the sea; others inhabit the lower reaches of coast streams; and still others resort to the shallows and mud flats of sheltered estuaries. There are also interior populations, of which some winter on rapid stretches of river that remain open even in the coldest weather. Probably these interior birds never visit the sea.

Finally there is a smaller number that nest in Canada and apparently winter somewhere in the western United States. These sometimes are seen in southern British Columbia during the spring and autumn migration.

British Columbia is a vast province. It has a coast-line, including the larger islands, of some 7,000 miles, and a hinterland larger than the combined areas of the States of Washington, Oregon and California. Parts of this large territory are unexplored; much of it is roadless wilderness, and in many places the traveller encounters serious difficulties in the matter of transport. It can be seen, then, that a complete tally of the winter population of trumpeter swans in British Columbia is a task of great difficulty that still awaits accomplishment. Many of the wintering grounds are difficult to reach and entail long journeys on foot. It would be impossible for even several observers to cover all the known wintering grounds in one season. Furthermore, some trumpeter swan populations are nomadic, shifting for one area to another, and not always appearing in the same place for two successive years. Thus definite information as to possible increase or decrease in numbers is restricted to those populations under regular protection. These bands, it is believed, represent about one-third of the population.

If a winter census was difficult, a summer search for nesting grounds in British Columbia was even more so, and much less fruitful. Up to the present no naturalist has reported finding a nest in British Columbia. During an investigation in the central part of the province in 1944 numerous Indians and woodsmen were asked for information on this question, and, with a few exceptions to be noted later, the reply invariably was that all the swans went north. Thus, at a meeting of Indians at Nazko, which 30 attended, all agreed that no swans nested in the country known to them, that is, the Blackwater and Euchiniko Valleys and the Nazko region generally.

The exceptions refer to single pairs of swans in occupation of a small lake, muskeg, or river, usually far removed from the ordinary paths of travel. Thus, an Indian tells of seeing a swan sitting on six eggs in a nest on a beaver lodge at Chiaz Lake, which is the headwaters of Chiaz Creek, about 29 air miles south-east of Quesnel. Other reports are: an adult and four young on Toboggan Lake near Smithers in the summer of 1934; a pair accompanied by young unable to fly on Tahtsa River at the outlet of Troitsa Creek in August, 1936, and a pair with one young on the Nechako River near Vanderhoof in the summer of 1938.

Assuming that the foregoing reports are correct, it would seem that trumpeter swans occasionally nest in central British Columbia. If they did so regularly, particularly if several pairs nested in close proximity, one would expect this knowledge to be current among Indians and other persons who travel the country in summer. This is not so, however, and the conclusion that the majority nest farther north, perhaps in Yukon Territory, seems warranted. It is of interest to note that trumpeter swans are reported to be common on migration as far north as Tetana Lake on the Driftwood River, which is close to 56° north latitude (John F. and Theodora C. Stanwell-Fletcher, 1943. *Occasional Papers No. 4, British Columbia Provincial Museum,* Victoria, B.C.)

Therefore the place of origin of the thousand or so trumpeter swans that winter in British Columbia remains obscure. It may be assumed, however, that part of the population is derived from a northern nesting ground extending into south-eastern Alaska and Yukon Territory. It can be assumed also that a large contingent is derived from the Peace River region of Alberta, where trumpeter swans are known to nest. J. Dewey Soper, who explored that region in the summer of 1944, found nests and adults with downy young. His count of the population was 64 adults and 14 cygnets. Since that time a Migratory Bird Officer has been employed to protect this nesting area of the trumpeter swan.

LIFE HISTORY

When white men first invaded the west they found trumpeter swans in summer, presumably nesting, in parts of Washington and Oregon, and in other places east to Iowa. On migration the swans travelled from northern points across the central and western states to southern wintering grounds in California and Texas. Travellers told of large numbers of swans encountered throughout the middle west. Still earlier, trumpeter swans had been seen on the Atlantic seaboard by the first settlers, and until the last quarter of the nineteenth century trumpeter swans visited Ontario on migration. Over most of this territory the species is now unknown. In addition to those referred to earlier as inhabiting British Columbia and Alberta, the only other known populations are in Yellowstone National Park in Wyoming and Red Rock Lakes Migratory Bird Refuge in Montana.

Undoubtedly the former, reportedly large, mid-western and eastern populations were completely wiped out. Two chief reasons, which complement one another, are offered to explain the disappearance of the species in the east and middle west and its great reduction in numbers throughout the far west. The first is apparent unawareness of danger as represented by man. The second is the once world-wide human desire for swans' down and the ease with which this could be supplied by killing the unwary trumpeter swan. It is a matter of record that between 1853 and 1877 one fur-trading company in Canada sold 17,671 swan skins, of which a large number undoubtedly were those of trumpeter swans. The traffic in swan skins continued at least as long as it was legal.

The first reason is undoubtedly valid. In comparison with the habitual wariness of the smaller whistling swan, the trumpeter is relatively fearless.

On many occasions in winter I have approached within 100 yards of a group of trumpeter swans standing on the snow-covered ice of a river margin. They might be relaxed in sleep with necks folded on their backs, in which position they appeared as so many cream-coloured mounds on the white snow. And they have been studied at close range while they searched for the tubers of sago pondweed, *Potamogeton pectinatus,* in the mud bottom of a marshy lake. At such times, when feeding in water of a depth of 18 inches or so, the necks are submerged to the shoulders. In deeper water the birds assume an almost vertical position, so that only the rear end of the body shows above the water. In this position all that can be seen is a white triangle – the end of the tail its apex – and the upper portion of the black tarsus, conspicuous against white plumage, as the bird paddles vigorously to maintain a vertical position. When trumpeter swans stand on some lake beach it is usually possible to approach them within easy observation distance provided some caution is used. Thus, at a small marshy slough near Vanderhoof a single immature bird remained standing on the muddy shore long after a flock of whistling swans, alarmed at my approach, had taken wing. Again, on a slough in the Cariboo region, two young of the previous year were observed at close range as they fed among a scant growth of dead rushes, 20 to 30 yards from shore. When two of us walked towards the slough the swans swam to the beach, walked up on it, and began dressing their plumage. At our closer approach they walked again into the water and swam slowly towards the centre of the slough. Many such instances could be related.

When trumpeter swans are carefully guarded they soon become accustomed to human presence and seem to be completely without fear when they are being fed, notably so at Lonesome Lake. On this lake the swans are in no danger of molestation by man. The problem there is to prevent starvation during sub-zero weather. Important items in their diet are water moss, *Fontinalis,* and several species of *Potamogeton.* When the supply of these foods is exhausted, or restricted by ice conditions, the swans are fed on water-soaked barley. The district is an isolated one. There is heavy snowfall and access is by ski or snowshoe. There are no roads. Because of these conditions it is necessary to bring in the winter supply of feed some time in advance. This is done by pack-horse in August or September, and the grain is stored in a mouse-proof cache close to the feeding ground.

The following is a summary of one season's enumerations of trumpeter swans on this area: October 2 – 2, October 27 – 14, November 4 – 40, November 29 – 57, January 1 – 60, February 18 – 80+. The number gradually decreased during March and the last was seen on April 2. The largest number of cygnets seen in one day was twenty-three.

Food

From observations of feeding trumpeter swans, it has been determined that the following foods are attractive to them, namely, the seeds of yellow pond lily, *Nuphar polysepala,* and water shield, *Brasenia Schreberi;* the tubers of sago pondweed, *Potamogeton pectinatus,* and the stems and foliage of similar species. Late in the season, when the supply of more desirable foods is low, the birds eat water moss, *Fontinalis* sp., the stems and roots of sedges, *Scirpus* sp., and whatever other aquatic vegetation can be secured. The gullet of an adult male that died from lead poisoning at Itatsoo Lake, Vancouver Island, in February, 1938, was packed with stems of grasses and sedges; the stomach contained 12 seeds of *Ceratophyllum demersum.* In an examination of the stomach contents of seven adults and two juveniles, killed by lead poisoning on Vancouver Island in January, 1946, Dr. I. McT. Cowan identified the following items, namely stems, leaves and roots of grasses, sedges (*Carex* sp.), and rushes (*Juncus* sp.), seeds of *Polygonum* sp., *Carex* sp., and wild cherry (*Prunus emarginata*). Another from Steveston, at the mouth of the Fraser River, had eaten grass roots, and seeds of a spike rush (*Eleocharis* sp.).

Restrictive Factors

The number of trumpeter swans dying from starvation in winters of more than average severity probably is a significant factor in population reduction. Many swans winter in sub-marginal territory where food is not abundant at the best of times and may become completely inaccessible at times of sub-zero weather, or at periods of high floods. In such times the swans stay on, in what probably is their ancestral wintering ground, to starve or to become, in their weakened state, victims of predators, rather than seek feeding grounds elsewhere. The situation is being met to some extent by artificial feeding, as has been noted, but winter populations in remote and inaccessible territory cannot be helped in this way.

Lead poisoning is a prevalent and important restrictive factor. Fortunately it occurs only in the more settled districts, where years of waterfowl shooting have resulted in an accumulation of shot in the shallows of lakes and rivers. Swans, like other waterfowl, require gravel in their gizzards in order to macerate food. In obtaining gravel it frequently happens that lead shot is ingested as well. In the ventricle the shot is comminuted by contact with gravel. It finally passes into the blood stream, where it produces paralysis and slow death.

At Vaseaux Lake, the trumpeter swan population was decimated, in January, 1925, as has been stated. In the preceding month, a period of exceptionally cold weather froze both Vaseaux Lake and the usually continuous open water adjacent to the Okanagan River outlet where the swans were accustomed to feed. Because of this circumstance the swans retreated to open water on Okanagan Lake, where they frequented the shallows at Crescent Beach, some 35 miles to the north. This particular area had been used frequently as a stand for trap-shooting and the lake bottom contained large quantities of shot, easily accessible to swans. At any rate two adult trumpeter swans and seven cygnets died there. The stomach of one specimen contained 451 lead shot. Later, six adults and two cygnets returned to the sanctuary, where they were seen on February 15 of that year. It was concluded, however, that some later succumbed to the effects of lead poison, for only six returned the following year. The band never regained its former strength and in a few years disappeared completely.

A more striking loss occurred on Vancouver Island in February, 1946. That winter a band of 15 trumpeter swans occupied a small, isolated pond, approximately 200 yards by 50 yards, in the coniferous forest. There was little food in the pond and the swans were accustomed to make daily flights to other feeding grounds. The exact location of these was not determined but manifestly they included areas which had been much shot over in previous years, for the birds ingested lead shot and at least 13 died from this cause. When the pond was visited in the morning of February 16, only four members of the flock were still alive. Two dead birds floated on the water and six others lay close together in the woods where they had died. Examination of the digestive tracts of 13 specimens revealed the presence of lead shot in each, ranging in number from two to 29 pellets.

Other instances of trumpeter swans dying from lead poisoning have been noted. In one instance an adult male died from the effects produced by five pellets. In the stomach of an adult female found dead there were 30 shot pellets, many of them worn flat by abrasion.

Death from gross multiple parasitism is a restrictive factor of unknown importance. There is one instance on record of an adult female trumpeter swan dying as a result of excessive parasitism by the cestode *Hymenolepis,* and the filarial nematode *Eurycerca* (I. McT. Cowan, *The Auk,* 63: 248-249).

Finally, there is the possible reduction of trumpeter swan populations by predation. About this little is known. Coyote and bald eagle signs have been observed about the carcasses of trumpeter swans on the Atnarko River and undoubtedly the animals had fed on these carcasses. There is no evidence that either had killed the swans. From the same place come observations of bald eagles in pursuit of swans, but no actual observation of a successful kill. It would seem probable that only sick swans, or those weakened by starvation, could be captured by predators. The data are insufficient to warrant a conclusion as to the effect of predation on trumpeter swan populations.

PROGRESS IN THE CONSERVATION OF NATURAL RESOURCES IN OREGON

By Warren D. Smith, University of Oregon

Introduction

Since the epoch-making conference called by President Theodore Roosevelt at the White House in Washington, D.C., December 18, 1908, the conservation movement has made great progress throughout the nation. It is the purpose of this paper to give a report of progress along this line in Oregon.

My own interest began when I attended a course of lectures at the University of Wisconsin by my old teacher of geology, the late Charles R. Van Hise, whose textbook was the first to be published on this subject in the United States. Later I had the privilege of visiting certain foreign countries where conservation was not practised and finally after I had been in Oregon I became identified with Forest Conservation Inc. and became familiar with the programme of sustained yield proposed for the Oregon and Californian revested lands. As a geologist doing field work I have been brought into contact with all branches of our natural resources.

During this year (1948) Oregon had the greatest percentage of gain in population, over 40 per cent, of any state in the Union. This influx of people will call for a greatly expanded use of our soils, trees, minerals and water, and therefore, not only wise development but sound conservation is imperative. In view of what has occurred and is taking place all over the world it behooves us to practise scientific conservation if the race between population and exhaustion of our natural resources is to be won. Hence the reason for this discussion. This is perhaps the most important problem facing us except the one of preventing another devastating war.

AGENCIES AT WORK IN OREGON

The following agencies are directly interested and active in promoting conservation in this state:

1. Forest Conservation Board (State).
2. State Forester.
3. U.S. Forest Service.
4. Forest Conservation Inc. (Private).
5. Oregon State Game Commission.
6. State Department of Geology and Mineral Industries.
7. State Reclamation Commission.
8. U.S. Bureau of Reclamation.
9. U.S. Army Engineers (Flood Control).
10. Willamette River Basin Commission.
11. Soil Conservation Service (Federal).
12. Fish and Wild Life Service (Federal).
13. U.S. Geological Survey (Water Resources Branch).
14. Land Management (Federal).
15. National Park Service.
16. State Parks Superintendent (State).
17. Keep Oregon Green Association (Private).
18. Society for the Preservation of Roadside Beauty (Private).
19. University of Oregon.
20. Oregon State College.

What we need in view of all these agencies is some over-all conservation commission to integrate their work. Unfortunately we in Oregon do not have such an organization. Many of our states do.

FOREST CONSERVATION

As lumber is Oregon's top industry at present and since we have the last great stand of merchantable timber in this country, our magnificent Douglas Fir, considerable attention is being given to the conservation of this valuable resource. For many years both the Federal Government and the State have taken many steps to protect our forests and rehabilitate cut-over areas and finally the lumbermen themselves, aware of what has happened in other states, have launched various programmes looking to sustained yield. These include, fire protection, selective cutting, tree farms, etc. At present attention is focussed upon a programme of co-operative sustained yield contracts between the Federal Government and private companies in the Oregon and California revested lands including some 3,000,000 acres in Western Oregon. Intermingled with these government-owned timber tracts are some 6,000,000 acres of privately-owned timber. Altogether they comprise an area as large as the State of Connecticut.

In the early days the government made a grant of every other section (one square mile) in a belt thirty miles wide on either side of the California and Oregon Railroad to that company under certain stipulations to promote settlement of the country. These stipulations were not complied with and these lands reverted, after a law suit, to the government. These checkered acreages, in part government and in part private, it is proposed to have developed under contract and under such regulations of the U.S. Forest Service as will insure sustained yield and greater utilization of all the wood. There has been vigorous opposition on the part of the small operators who have raised the cry of monopoly and favouritism of the larger companies. Recently public hearings have been held to get the facts and iron out the difficulties. As the Congress passed a law in 1937 providing for sustained yield on these lands it is now just a question of administration.

It should be said here in all fairness to some of the larger companies at least that they have seen the handwriting on the wall and are doing some very constructive work in the direction of sustained yield. Some of the difficulties come from the practices of some of the small operators, locally called "woodpecker outfits" whose operations are often wasteful and who apparently merely want to "cut and get out".

FLOOD CONTROL

Unlike California where there is a dearth of water Oregon has at times far too much and serious floods occur every so often both on the Columbia and the Willamette Rivers. Those on the Columbia usually come in June, while those on the Willamette in December and January. In June of this year (1948) an unusually destructive flooding of the Columbia caused millions of dollars damage in the area between the Dalles and Astoria (lower Columbia) and wiped out the homes of 18,000 people in the Vanport district of Portland.

The peak flow of the Columbia, 1,010,000 cubic feet per second, was only some 390,000 sec. feet less than the peak flow of the Mississippi River including all of its tributaries draining 40 per cent of the United States according to a recent statement of the U.S. Geological Survey.

In this connection it might be mentioned that there is considerable agitation in favour of a Columbia Valley Authority patterned on the well-known and highly successful Tennessee Valley Authority.

To remove, or at least ameliorate these conditions the U.S. Army Engineers are engaged in an extensive programme involving the building of dams, revetments, river straightening, etc., and all calling for the expenditure of many millions of dollars. Some of the dams will be for flood control only, others will provide power and water for irrigation. There has been considerable friction between the engineers and the agencies interested in fish and wild life, but many of the difficulties are now being straightened out.

SOIL EROSION

Oregon has an active Soil Conservation Commission headed by the director of the State agricultural experiment stations and under its guidance soil conservation districts have been set up throughout the state and much progress has been made in this field.

The work is of course closely related to forest management and flood control and the various agencies at work on these problems co-operate in many ways.

Especial attention is being given to sheet flood erosion and wind erosion in the semi-arid areas in the eastern part of the state where this has become a serious problem.

A forward step in conservation of grazing areas of the nation was taken by the Federal Government with the passage in 1935 of the Taylor Grazing Act which limits the promiscuous grazing on public lands. In the south-western states considerable opposition to the operation of this Act has developed but it is believed that the administration of it in Oregon has met with more success. The chief friction seems to be between the sheep and cattle men.

Of course, an important part of conservation is the development of irrigation on lands otherwise lying idle and Oregon has gone in for an advanced programme of irrigation sponsored by the State College. Many irrigation districts have been formed and large irrigation projects have been started. One of the most important is in Central Oregon near the town of Madras, where 50,000 acres were being brought into production within the last year or two.

One of the most constructive pieces of reclamation work in this state is being carried out by the Rotary Club of Lakeview in the semi-arid region of South-Central Oregon. Due to over-grazing much of the surrounding country had been reduced to sagebrush land. This club has undertaken to finance the ploughing up of the sagebrush and reseeding the land with the seeds of especially selected grasses. If this experiment is successful it may prove to be the means of reclaiming millions of acres in the region west of the Rocky Mountains.

Wild Life Preservation

Recently several wild life reservations have been set up in the state especially for game birds and antelope. Oregon also has strict game laws and hunting is restricted to certain times of the year, and each hunter is limited as to the number of each species he can shoot. The state programme is aided by such organizations as the Audubon Society and the Fish and Wild Life Service of the National Government. Owing to the large areas segregated in the National Forests, National Parks, Monuments and Primitive areas the activities of hunters are pretty much restricted.

As Oregon's many streams abound in fish the Fish Commission has strict laws relating to fishing and maintains many fish hatcheries for the restocking of our streams and lakes.

At the new flood control dams being built fish ladders are provided to enable such fish as the salmon to get up stream to the spawning grounds.

Scenery

Within late years the people of the state have come to realize the importance of preserving and promoting its *great* scenic features. Many years ago the Federal Government established the world-famous Crater Lake National Park and the Oregon Caves National Monument with very strict regulations for their use by the public.

The state has at present over eighty State Parks embracing over 40,000 acres varying from less than one to 7,000 in area. Some of these areas have been selected solely for their scenic or recreational value, while others have been chosen either for historical or scientific interest. One of the latest to be created is the John Day Fossil Beds Park, the classic hunting ground of Condon, Merriam and others. Here we find an almost complete Tertiary section, in fact, according to the late John C. Merriam, one of the finest geological sections in North America.

Aside from the great scenic and recreational values our tourist business in 1947 amounted to about 100,000,000 dollars.

Under the sponsorship and guidance of the late Dr. Merriam, already mentioned, a committee called the Advisory Committee on the Educational Problems of Oregon Parks was created by the State System of Higher Education consisting of geologists from Oregon and California principally who had done research in the state. The State Parks Commissioner is a member ex-officio of this committee. It is the purpose of this committee to promote an understanding and appreciation of the scenic and geological features of the state and to acquaint, by means of suitable publications, the laymen with the value and meaning of these.

At the University and the State College courses in conservation are offered and likewise in the state-wide Extension Division of the system of Higher Education courses are offered for communities outside of the state educational institutions. This programme has been expanded to include radio programmes.

CONCLUSIONS

At the present time the great demand on our timber resources for all sorts of construction purposes both here and abroad makes it difficult for us to check the inroads upon our forests. In Lane County, which is one of the two principal forested counties, the cut of timber in 1947 amounted to over one million board feet of lumber. In fact we are cutting our trees at present faster than they are being replaced by new growth. This of course has brought great prosperity to our section of the state, but some of us are looking with some concern toward the future. The conservationists find themselves often in conflict with commercial interests and our road is not an easy one. However the public has been thoroughly aroused to the dangers ahead and a constitutional amendment authorizing indebitness for state reforestation was voted on by the people on November 2nd. At last accounts, however, this important measure appears to have been lost by a narrow margin.

It can be seen from the foregoing brief survey that the people of this state are thoroughly aware of the importance of conservation and are doing something about it and this writer feels that great progress has been made, although much remains to be done before our economy can be permanently stabilized.

THE STATUS OF STELLER'S ALBATROSS

By Oliver L. Austin, Jr., Natural Resources Section, G.H.Q., S.C.A.P.

[*Abstract*]

The short-tailed or Steller's albatross, *Diomedea albatrus*, formerly bred abundantly on isolated islands south of Japan. The most famous and probably the largest colony that ever existed nested on Torishima in the Seven Islands of Izu, where from 1890 to 1903 the Japanese slaughtered over 5,000,000 of them for the feather trade. Smaller colonies are known to have bred in the Bonin and southern Ryukyu Islands. The species spent the non-breeding season between April and November pelagically in the North Pacific, ranging the open seas from the China coast north to Kamchatka and Alaska, and east to southern California.

The remnants of the Torishima colony were apparently wiped out in 1933 by the Japanese, and an eruption of the island's volcano in 1939 destroyed their old breeding ground completely. No definite reports of Steller's albatross have been made since the last birds were killed on Torishima in 1933. The most recent specimens are six birds now in the Yamashina Museum, collected on Torishima in April, 1932. A few sight records of varying degrees of reliability have been reported since 1933, mostly in Aleutian waters, the latest in June, 1945, but none that are absolutely unquestionable. The species cannot be regarded definitely as extinct until competent observers have visited all its known former breeding spots. As these are all in waters which have swarmed with Japanese fishing boats throughout the last several decades, the probability of any remnant colonies surviving is remote.

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THE PRESENT STATUS OF THE PROTECTION OF BIRDS AND MAMMALS IN JAPAN

By Nagamichi Kuroda, Game Management Division, Bureau of Forestry, Ministry of Agriculture and Forestry, Japan

(1) Introduction

In Japan the protection of birds and mammals has been effected by virtue of the Game Law as well as by the activities of the Game Management Division, Bureau of Forestry in the Ministry of Agriculture and Forestry, and the Committee for Preserving Scenic, Historic, and Natural Monuments in the Ministry of Education (formerly assigned to the Ministry of Home Affairs). Reports of investigations and researches concerning birds and mammals and their protection have been made principally by the late Prof. Dr. Watase, Dr. Uchida, Prof. Dr. Kaburaki, and myself. This report has been prepared for the purpose of making a brief survey of the protection at present given to birds and mammals in Japan.

(2) Hunting Licences and Hunting Seasons

The present Japanese Game Law was promulgated in 1919 and last revised in 1925, necessary amendments being made in 1947. A new code is now being drafted for presentation to the Diet early in 1949, which adds many desirable reforms, in keeping with the new Constitution.

Hunting licences are issued by the Prefectural Governors. The Game Law now in force imposes a fixed tax on the hunter in accordance with the income tax he paid the previous year: 4,800 yen for those who pay over 10,000 yen income tax; 2,400 yen for those who pay less than 10,000 yen tax; 1,000 yen for all others. Two classes of licences are issued, one for those hunters using firearms, the other for those who use nets for ducks.

The open hunting season extends from November 1st to the end of February each year, except in Hokkaido, where it extends from October 1st to January 31st.

(3) PROTECTION OF WILD BIRDS AND MAMMALS BY THE GAME LAWS

The Game Law in force in Japan prohibits hunting except in the open season. A list of animals and birds that can be hunted is published by the Government and it is absolutely prohibited to hunt at any time wild birds and animals not specified in the list. The following 48 species of birds are now listed as legal game.

Night Heron (1)[1], Japanese Quail (1), Japanese Hazel Grouse (1), Chinese Bamboo Pheasant (1) (introduced), Ducks (25, excluding Mandarin Duck), Mergansers (3), Geese (2, including Bean Goose and White-fronted Goose only), Indian Water-Hen (1) and Coot (1), Snipe (3, including Common Snipe, Latham's Snipe and Swinhoe's Snipe) and Woodcock (1), Eastern Turtle-dove (1), Crows (5, excluding Nutcrackers), Japanese Tree-Sparrow (1), and Russet Sparrow (1). All species of mammals are legal game except Japanese Serow, female Japanese Mink, Otter, Small-eared Cat (wild cat of Tsushima), Japanese Macaque, and female Japanese Deer.

The open season on Korean ring-necked Pheasant, Green Pheasant and Copper Pheasant is from November 1st to December 31st.

The open season is from December 1st to end of February for the following game mammals:

Japanese Badger, male Japanese Mink, Japanese Red Fox, male Japanese Deer, Japanese Racoon Dog, Japanese Yellow Marten, Japanese Large Flying Squirrel, and Squirrels (Hokkaido, Honshu and Kyushu).

All other birds and mammals than those listed above are protected at all times.

Protection is given to most wild species of birds for the following three reasons:—Those useful to agriculture and forestry, those useful to aquatic products industry or fisheries, and rare birds which must be preserved because of their scarcity.

In September, 1947, orders abolishing mist netting and the use of bird-lime were promulgated, and shooting from automobiles, power boats, and aircraft prohibited. The use of air-guns is also forbidden without licensing. A bag limit has been established for the first time in Japan, as follows:

Names of Birds	*Daily Bag Limit*
Pheasants and Copper Pheasants	3
Hazel Grouse	3
Chinese Bamboo Pheasant	5
Japanese Quail	5
Eastern Turtle-dove	10
Indian Water-Hen and Coot	5
Snipe and Woodcock	10
Bean and White-fronted Geese	2
Ducks	10

Duck netters are limited to 900 ducks during the open season. The following three species were added to the non-game list in September, 1948: Eastern Water Rail, Japanese Ruddy Crake, and Painted Snipe.

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[1] Figures in parentheses indicate the number of species. Subspecies also can be hunted, but their numbers are not included in the above figures.

(4) THE PRESENT STATUS OF HUNTING IN JAPAN

The multiplication of people in cities, towns, and villages, the steady increase of hunters in our country, and the cutting down of forests have been major causes of the decrease of wild birds and mammals in general, which is becoming more noticeable year after year. The phenomenal increase of hunters in our country in the last few years is evidenced by the following table:

Year	Licence for Netting	Licence for Firearm Hunting	Total
1941	9,650	105,244	114,894
1942	9,629	116,883	126,512
1943	9,946	110,578	120,524
1944	10,141	110,795	120,936
1945	13,446	120,626	134,072
1946	19,292	147,997	167,289

By December, 1948, 142,257 hunters' licences were issued.

Until 1947, almost all Japanese wild birds and animals were hunted, with few exceptions. In a single season hunters reported killing more than 2,650,000 Dusky Thrushes and 1,700,000 Bramblings, as well as about 500,000 - 570,000 Japanese Hares (including Echigo Hares) and about 97,000 - 140,000 Japanese Minks. After September, 1947, however, the bag limit already mentioned stopped much abusive hunting, and all the song and insectivorous birds are now protected. Beneficial or rare mammals also are guarded from extermination by the limited open season. According to recent information received from several prefectures, Green Pheasants have not yet increased mainly because of poaching, and their status is far from our ideal. But the Copper Pheasants in northern Honshu have been gradually increasing. The unique Japanese Serows and the Japanese Red Foxes are reported as multiplying.

(5) PRESERVES ("KINRYOKU")

The preserves and sanctuaries established under the present Game Law are areas where hunting is prohibited for a fixed term, not exceeding ten years, to ensure the protection and multiplication of wild birds and mammals. At present 67 national and 149 prefectural preserves protecting breeding grounds of song and insectivorous birds, havens for migratory birds, sea-bird colonies, and the like, are authorized, scattered all over the country. One of the best sanctuaries for song and insectivorous birds is the northern slope of Mt. Fuji, 30,000 hectares in area. 174 species and subspecies of wild birds are found there, of which 114 forms breed there. Sanctuaries at Misakimura and Machinomura, Ishikawa Prefecture, protect the large numbers of thrushes and small Fringillidae which migrate every autumn across the Japan Sea from the mainland. Lakes, beaches, and marshes situated on the migration route of waterfowl, egrets, curlews and plovers are specified as sanctuaries, such as the Ariake Sanctuary in Kyushu. For sea bird sanctuaries, the breeding places of the Black-tailed Gulls at Kabushima in Aomori Prefecture, Tsubakijima in Iwate Prefecture, and others, are notable.

At Kushiro in Hokkaido, the only breeding place in Japan of the Japanese or Manchurian Crane is a sanctuary. In Hyogo Prefecture we have the famous Tsuruyama Sanctuary, where Japanese Storks breed, which, it is a great pity to note, was disturbed by the local inhabitants during the war.

Netting preserves belonging to the Ministry of the Imperial Household along the Yedo River in Saitama and Chiba Prefectures are sanctuaries for many species of wild birds. Flocks of geese find shelter here during winter and spring, and thousands of ducks enjoy life safely in the duck decoy ponds from autumn to spring in these preserves. Grey Herons, Night Herons, Egrets, Cormorants, Water-hens, Crakes, Snipe, Green Pheasants and such rare species as the Eastern Ring Dove and the Japanese Blue Magpie can be easily observed there. The dove has now become quite rare and its numbers are still decreasing from poaching.

(6) AREAS WHEREIN HUNTING BY MEANS OF FIREARMS IS PROHIBITED ("JURYO KINSHI KUIKI")

At present there are 154 areas of this type authorized, where shooting is prohibited, mainly as a public safety measure in parks, shrine and temple grounds, green belts, and the like.

(7) AREAS WITHIN THE LIMIT OF WHICH THE HUNTING OF SPECIAL KINDS OF ANIMALS IS PROHIBITED.
("HOKAKU KINSHI KUIKI")

At present there are 54 acres of this kind throughout Japan designed to save certain wild birds and mammals of special kinds within their boundaries. To point out a few examples, a large area in Nagano Prefecture is so designated to protect Japanese Serows. Japanese deer are protected in this way throughout six prefectures of the Chugoku District in North-western Honshu. The Shodoshima Area in Kagawa Prefecture in the Inland Sea of Japan is reserved for the protection of Japanese Deer and Japanese Macaques.

(8) HUNTING AREAS ("RYOKU")

These are established by the State, Prefectural, town, or village authority as areas wherein hunting is permitted under rigid controls to maintain the population of wild birds and mammals, to prevent abusive hunting, and to facilitate the work of artificial propagation. Within these preserves hunting is permitted only on specified days, in most cases Sunday, and the number of persons hunting is also limited in accordance with the area of the land and the game available. An entrance fee is charged, and the proceeds are used for the upkeep of the preserve. At present in Japan there are 91 Hunting Areas in all, of which one is managed directly by the State.

(9) JOINT HUNTING AREAS ("KYODO-SHURYOCHI")

These hunting areas, sometimes called "Villager's Hunting Grounds", are established to maintain the population of certain wild birds or mammals where they are hunted with special tools. Since the olden days, people in rural villages in Japan netted ducks in swamps, lakes, and ponds which they owned in common in their respective villages. The Game Law recognizes the privilege enjoyed by these villagers, and prohibits other hunters trespassing on the areas. At present 13 of these traditional netting areas remain where the inhabitants use nets exclusively for catching ducks. The most remarkable of these Joint Hunting Areas are Tega-numa and Wada-numa in Chiba

Prefecture. The former place is one of the leading sources of supply of ducks consumed in Tokyo. After the Pacific War, however, the ducks in the Tega-numa Hunting Area have been disturbed by the use of firearms by some misunderstanding persons. It is very regrettable, and we hope soon to stop firearm hunting in this hunting area as before.

(10) SANCTUARIES FOR DUCKS

There are now in Japan five duck decoy ponds, two of which, one in Saitama and one at Shinhama in Chiba, belong to the Imperial Household. The three others are at Murayama, a suburb of Tokyo; at Kozukue near Kanagawa; and at Bentenike in Hyogo Prefecture. At the Imperial Household Duck Decoy Ponds from 3,500-4,000 ducks on the average are caught during each season, while the remaining 90 per cent stay on the same pond and pass the winter months. These ducks go back to the north in spring and multiply. In other words, the duck decoy pond is an artificial protective zone or sanctuary for water birds. It is earnestly hoped that decoy ponds of this kind will be increased in this country. Possibly these ponds will be named as "Special Experiment or Hunting Areas" by the proposed new Game Laws and used for research and study of duck migration by banding, methods of attracting migratory waterfowl, and to preserve this unique hunting method.

(11) GAME ADMINISTRATION AND ORGANIZATIONS FOR INVESTIGATION OF WILD BIRDS AND MAMMALS

The Game Administration and institutions for the protection and propagation of wild birds and mammals are placed under the jurisdiction of the Game Management Division, Bureau of Forestry, Ministry of Agriculture and Forestry in Tokyo. Experts are stationed at prefectural offices to oversee local protection of wild birds and mammals. The principal investigations carried on by these institutions deal with the relation between birds and mammals and agriculture and forestry, their food habits, migration, ecological researches, etc.

An Experimental Station for birds and mammals on the outskirts of Tokyo breeds game birds, particularly pheasants and partridges of different species, and distributes them throughout the country. Nesting boxes for insectivorous birds also are distributed everywhere in the country to help propagate them. According to Dr. Uchida, 18,742 nesting boxes were distributed all over the country by this station in 1925 and a little less than half of them were used by insectivorous birds, such as Grey Starlings, Tree-Sparrows, Great-Tits, Varied Tits, Coal-Tits, Nuthatches, Woodpeckers, Owls, etc. The nest boxes have been injured by men, squirrels, flying squirrels, dormice, long-tailed field mice, snakes, bees, or wasps, etc.

About 100 stations for researches on migratory birds were formerly installed at lighthouses, meteorological observatories, schools, and others to supply reports on migration. Since the Pacific War, however, these places have stopped reporting, but we are now trying to reestablish them. Experimental bird-banding which was begun in the autumn of 1924 but was discontinued during the war, is now being started again.

(12) PROTECTION OF BIRDS AND MAMMALS BY LAW FOR PRESERVING SCENIC, HISTORIC, AND NATURAL MONUMENTS

In addition to those wild birds and mammals protected by the Game Law from abusive hunting, others are given added protection by designation as "Natural Monuments" by the Law for Preserving Scenic, Historic, and Natural Monuments, enacted in 1919. The following birds and mammals have since been conserved by it:

Hokkaido.

- Breeding place (Oshima, Matsumae-mura) of *Puffinus leucomelas.*
  Defined in March, 1928.
- Breeding place (Kushiro) of Japanese Crane, *Grus japonensis.*
  Defined in June, 1935.
- Breeding place of sea birds (mostly *Uria aalge inornata*) on Teure Shima.
  Defined in August, 1938.

Aomori Prefecture.

- Breeding place (Kabushima) of *Larus crassirostris.*
  Defined in March, 1922.
- Winter haunt of Swans (*Cygnus cygnus*) at Kominato.
  Defined in March, 1922.
- Breeding place (Saruga Shrine) of Cormorants (*Phalacrocorax carbo hanedae*), Egrets, and Herons.
  Defined in December, 1935.

Iwate Prefecture.

- Breeding place (Tsubakijima) of *Larus crassirostris.*
  Defined in December, 1934.
- Breeding place (Sanganjima) of *Puffinus leucomelas* and *Oceanodroma monorhis monorhis.*
  Defined in December, 1935.
- Breeding place (Hideshima) of *Oceanodroma castro castro.*
  Defined in December, 1935.
- Iwaizumi Stalactite Grotto of Insectivorous Bats.
  Defined in December, 1938.
- Winter haunt of Swans at Kotomo.
  Defined in November, 1941.

Miyagi Prefecture.

- Breeding place (Enoshima) of *Larus crassirostris.*
  Defined in January, 1934.

Yamagata Prefecture.

- Breeding place (Tobishima) of *Larus crassirostris.*
  Defined in December, 1938.

Fukushima Prefecture.

- Haunt (Terushima) of Cormorants.
  Defined in February, 1945.

Saitama Prefecture.

- Breeding place (Noda-mura) of Egrets and Night Herons.
  Defined in December, 1938.

Yamanashi Prefecture.

- Saiko Komori Ana (a bat-cavern).
  Defined in December, 1929.

Haunt (Kitakoma-gun) of Albino Squirrels.
Defined in August, 1914.
Breeding place (Minobu-machi) of *Eurystomus orientalis abundus* Ripley.
Defined in December, 1937.

Nagano Prefecture.
Breeding place (Mitake-mura) of *Eurystomus orientalis abundus.*
Defined in June, 1935.

Gifu Prefecture.
Breeding place (Suhara Shrine) of *Eurystomus orientalis abundus.*
Defined in June, 1935.

Aichi Prefecture.
Breeding place (Unoyama) of *Phalacrocorax carbo hanedae.*
Defined in January, 1934.

Kyoto Urban Prefecture.
Breeding place (Kanmurijima, Sea of Japan) of *Puffinus leucomelas.*
Defined in December, 1924.

Hyogo Prefecture.
Breeding place (Tsuruyama) of *Ciconia ciconia boyciana.*
Defined in March, 1921.

Shimane Prefecture.
Breeding place (Fumishima) of *Larus crassirostris.*
Defined in March, 1922.
Breeding place (Hoshinokami-shima) of *Puffinus leucomelas.*
Defined in May, 1938.
Breeding place (Okinoshima) of *Puffinus leucomelas.*
Defined in February, 1940.

Hiroshima Prefecture.
An excursion surface for Black Finless Porpoise (*Neophocaena phocaenoides* (Cuvier).
Defined in November, 1930.
Winter or spring haunt (sea surface) of Divers (*Colymbus stellatus* and *C. arcticus pacificus*).
Defined in February, 1931.

Yamaguchi Prefecture.
Winter haunt (Yashiro-mura) of Cranes.
Defined in March, 1921.
Haunt (Mukojima) of Japanese Raccoon Dog (*Nyctereutes procyonoides viverrinus*).
Defined in February, 1926.
Bat Cavern at Oboya.
Defined in March, 1928.
Migrated Haunt (Kabeshima) of Cormorants.
Defined in May, 1934.
Migrated haunts (Kawashima and Asofu) of Egrets.
Defined in December, 1935.

Nagasaki Prefecture.
Tristram's Woodpecker (*Dryocopus richardsi*) in the Tsushima Islands.
Defined in October, 1922.

Winter haunt (Isahaya-machi) of Mandarin Ducks (*Aix galericulata*).
Defined in November, 1931.

Miyazaki Prefecture.

Haunt (Koshima) of Japanese Macaques (*Macaca fuscata fuscata*).
Defined in January, 1934.

Breeding place (Sano Shrine) of *Eurystomus orientalis abundus*.
Defined in May, 1934.

Kagoshima Prefecture.

Winter haunt (Akune) of Cranes.
Defined in March, 1921.

Colonies of introduced Korean Magpies (*Pica pica japonica*)—Fukuoka and Saga Prefectures.
Defined in March, 1923.

Japanese Ptarmigans (*Lagopus mutus japonicus* Clark) in the Japan Alps.
Defined in March, 1923.

Breeding place (Mt. Hiei) of various song and insectivorous birds—Kyoto Urban Prefecture and Shiga Prefecture.
Defined in October, 1930.

Japanese Serows (*Capricornis crispus*) of 13 prefectures of Honshu.
Defined in December, 1934.

Breeding place (Sado Island) of Japanese Crested Ibises (*Nipponia nippon*)—Niigata and Ishikawa Prefectures.
Defined in December, 1934.

In addition, many Japanese breeds of the domestic fowl, such as the Long-tailed Fowl, Totenko, Uzura-chabo, etc., of Kochi Prefecture; the domestic horse and cow (Ushiuma of Tanegashima; Mishima-ushi of Yamaguchi Prefecture); and Japanese domestic dogs of seven breeds (Akita, Yamanashi, Wakayama, Mie, Ishikawa, Toyama, Fukui, Gifu, Nagano, and Kochi Prefectures and Hokkaido) have also been defined as Natural Monuments previous to February, 1945. Recently, in March, 1948, Daikokujima, off Akkeshi in Hokkaido, has been designated provisionally. On this small island, *Larus schistisagus*, *Oceanodroma leucorhoa leucorhoa*, *Cerorhinca monocerata*, *Lunda cirrhata*, and *Phalacrocorax capillatus* have been recorded as breeding.

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THE PROTECTION OF NATURE IN THE PACIFIC WITH RELATION TO THE NEW DEVELOPMENT OF A WORLD APPROACH TO INTERNATIONAL CONSERVATION

By Harold J. Coolidge, Pacific Science Board, National Research Council, Washington, D.C.

All of those who are concerned with the Protection of Nature, which was defined in the preamble to The Constitution of the newly formed International Union for the Protection of Nature as: "the preservation of the entire world biotic community, or man's natural environment, which includes the earth's renewable natural resources of which it is composed, and on which rests the foundation of human civilization . . .", will be gratified by the attention which is being devoted to an international understanding of problems in this field through the three world and two regional conferences which are being held in the current ten months to consider international conservation problems including those in the Pacific area.

Last September the Inter-American Conference on the Conservation of Renewable Natural Resources was held at Denver. Many of the participants felt that the well-planned field trips contributed vitally to the success of the Denver Conference. The field trips were an integral part of the Conference and provided first-hand examples and demonstrations of conservation practices, such as erosion control, which were being discussed at the Conference. This Congress provides, on an even broader scale, the opportunities for such first-hand examples and demonstrations which can contribute to the success of our deliberations here.

The discussions, which took place at Denver, led to recommendations that are of concern to the Pacific countries in the Americas and that also might well be considered by any Pacific regional group that might wish to take constructive action along similar lines. The Pacific region is handicapped by not having a central agency, such as the Pan American Union, which could serve as a point of co-ordination and administration as well as a source of financial support for this type of endeavour. Let us hope that it may be possible for the South Pacific Commission to play a role in this area somewhat similar to that of the Pan American Union in the Americas.

For example, one of the recommendations calls for " . . . the Pan American Union, working in close relationship with the FAO, with other organizations of the United Nations and with the Inter-American Institute of Agricultural Sciences, [to] assume the leadership in:

> (a) Promoting the development of co-operation among the countries of the Western Hemisphere with respect to governmental activities pertaining to the development and conservation of renewable natural resources;
>
> (b) Establishing an ample service to assist governments in obtaining the best scientific and technical advice available, including that particularly pertinent to the making of watershed surveys, resource inventories, and the land classification studies;
>
> (c) Publishing and distributing periodic reports, summarizing the scientific work being done in the various countries and the particular problems needing special attention, as well as suggesting methods and procedures for coping with these problems . . ."

It would seem that these matters are just as important in this part of the world as they are in the Americas.

The second regional conference which I have referred to is the one in which we are engaged here. Among the many problems to which we should give our best thought is whether the Pacific and Asiatic countries wish to establish a regional Convention, profiting by the strong points and avoiding the weakness in the London African Convention (1933) and the Western Hemisphere Convention on Nature Protection and Wildlife Preservation (1941). Many of you will remember that Lord Onslow made such a proposal, and the plans for a meeting were already developed when the outbreak of World War II led to a postponement. Since the War, I believe it is thought that matters of this sort might well be handled through the United Nations' specialized agencies which are showing an increasingly active interest in these matters.

It has been suggested that, while important results have been achieved by both the African and the Western Hemisphere Conventions, it would be well to consider the careful preparation of a World Convention, which would incorporate the benefits from the best features of each, and add some effective means of assuring a better or more uniform enforcement. There were those who felt that such a Convention should be prepared by the UNESCO-IUPN Conference on the Protection of Nature next June, but the discussions at the

UNESCO symposium at Fontainebleau clearly revealed that time was much too short and the matter far too important to enable it to be dealt with at the above Conference, except in a very preliminary way. It would certainly be helpful if that meeting could determine whether most countries did favour such a World Convention and, if so, what form it might take and how the preparatory work should be divided up, on a regional and as well as on a substantive basis. In any plans for such a Convention, special study and emphasis must be given to the roles of National Parks, Wilderness Preserves, and reservations of all kinds. The needs of the Pacific region for a Convention of some sort should have a great influence on the course of action to be adopted by the UNESCO-IUPN Conference on the Protection of Nature.

Another matter that will be on the agenda of the UNESCO-IUPN Conference is a discussion of the status of the rare and vanishing species of flora and fauna in all parts of the world. It seems to me that, if the spotlight of world public opinion could be turned on certain sore spots where species are in eminent danger, it may be possible, through such mass media as the press and radio, to bring pressure on the local authorities to take appropriate measures to help assure their survival and win the approval of world public opinion.

If the world would show its concern over the survival of the last group of *Rhinoceros sondaicus* which have been carefully preserved in the Oedjoeng-Koelon Reserve in Pandeglang, on Java, which lies in the area that has been controlled by the Indonesian Republic, if it were publicly spotlighted as the plight of the displaced island inhabitants of Bikini, there might be hope of protecting these rhinos from being poached and sold for Chinese medicine. Once a natural species has become extinct it can never be replaced.

We are thankful, for example, that the kiwi and *Sphenodon* are examples of rare species that have been saved from extinction in this part of the world, and are protected by appropriate legislation. It is my hope that the Brussels office of the new International Union for the Protection of Nature may serve as a "survival office" to serve as a watch dog for many vanishing species.

Other subjects that have been projected for the agenda of the UNESCO-IUPN Conference on the Conservation and Utilization of Natural Resources, are: Conservation education on a world-wide basis at all school and college levels; the role of a central office and other steps that should be taken to stimulate an exchange of information about the Protection of Nature in all countries; the problem of vanishing big game herds in Africa and India; and international collaboration in the field of ecological research.

It is also important that the planners for the utilization of resources for power and recreation should be made very aware of the destructiveness of some of their practices, such as the effect of dam building on forest vegetation and habitat which is so essential to the preservation of wildlife.

It would be most helpful if this committee, or the Council of the Pacific Science Association, would establish a Committee to assist the IUPN and UNESCO with the preparations for the forthcoming Conference and the development of papers and discussions for these meetings which will be of greatest benefit to Pacific countries.

I have already mentioned in passing the United Nations Economic and Social Council Conference in the Conservation and Utilization of Resources. This Conference will probably be held in June at Lake Success and its principal purpose will be for " . . . exchanging information on techniques in this field, their economic costs and benefits, and their inter-relations . . ."

The Conference is to be scientific rather than policy-making. It will have no power to bind governments and it will not formulate recommendations to them. The primary concern of the Conference is with the practical application of science to resource management and human use rather than with minute refinements in research and scientific methodology. Effective utilization of even a single resource calls not on one science but on many. For example, "the fullest use of water requires balancing the competing claims of power, irrigation, navigation, flood control and other benefits. Moreover, it is often necessary for the sound development of a particular area to plan jointly the utilization of its agricultural, mineral and power resources and their joint use in the expansion of industry".

It is essentially a technical conference for the mutual exchange of information, and, unlike the Conference on Nature Protection, which will probably follow immediately after, it will not adopt resolutions or recommendations to Governments.

I have left until last my special reference to the successful Fontainebleau Conference, which was held at the invitation of the French Government in association with UNESCO and with assistance from the Swiss League for the Protection of Nature. At that Conference there were 130 participants representing 123 conservation organizations and 34 countries. The Pacific countries which were represented as governments or by organization delegates were: Australia, Canada, France, Mexico, Netherlands, New Zealand, Panama, Peru, Siam, United Kingdom, and the United States.

It is to be sincerely hoped that all countries, as well as private and semi-governmental organizations represented at this Congress, which have any interest in conservation will join the new Union and give it their full support. A place was left open on the Executive Board for someone to be chosen from the Pacific area and nominations from this Congress will be welcomed.

One of the outstanding features of the Fontainebleau Conference was a symposium, held under the auspices of UNESCO, dealing with such subjects of special interest to the Conference as: Legislation and action by governments to preserve nature; the scientific management of wild life; big game conservation in Africa; concepts of national parks and conservation areas; fauna conventions and international legislation; discussion of the relationship of the UNSCCUR to the proposed UNESCO Conference.

Some people are confused by the plethora of International Conferences that are coming so thick and fast, and they fear a duplication of function between UNESCO, FAO and the new IUPN.

Each Conference, like our own here, has something to contribute to the next, and the planning of the UNSCCUR and UNESCO-IUPN World Conferences is being integrated so that they will supplement and in no way duplicate each other. Many of the same individuals will wish to participate in both. As for the new Union, it can be in a strong position to assist UNESCO and FAO in the large job that they have ahead, particularly in the field of conservation research and education. The Union is under contract now to help in the technical aspects of preparing one of the Conferences. There is so much to be done, and funds for support are so difficult to procure if the job is entirely confined to one agency. I am sure that there will be close cooperation without waste or duplication if everyone puts his shoulder to the wheel, and encourages all the UN agencies to work with the Union in furthering our conservation objectives, and encourages the continuing development of a World Approach to International Conservation.

In conclusion, I would like to point out the grave concern that we all have for the preservation of the last surviving remnants of endemic flora and fauna on many Pacific Islands, and the danger of the introduction of exotic species as evidenced by some of the well-known problems of wildlife management now facing the governments of New Zealand and Australia.

It seems to me vitally important that all of us who are from Pacific countries should make sure that our Governments and, as far as possible, our private organizations are strongly and effectively represented at the UNSCCUR and UNESCO-IUPN Conferences in June, as well as in the membership of the newly-created International Union for the Protection of Nature with headquarters at Brussels. Our delegates should also see that conservation problems in the Pacific area receive attention and, where possible, that active efforts toward solution of these problems are made without delay. The Pacific Science Board will do what it can, but all of you who are here can do far more, especially with government backing.

At the conclusion of this paper, Professor R. Heim read his "Notice of the formation of the International Union for the Protection of Nature".

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